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CLAIMS

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(57) [Claim(s)]
[Claim 1] The semiconductor device which comes to have two or more electrodes which consist of one or more sorts of ingredients chosen from the group which consists of the platinum and gold which touch a fullerene thin film and this, silver, copper, aluminum, an indium, the tin oxide, indium oxide, a zinc oxide, and carbon, and is characterized by at least one electrode being an aluminum electrode.
[Claim 2] The semiconductor device according to claim 1 characterized by a fullerene thin film being a thin film which consists of carbon clusters.
[Claim 3] The semiconductor device according to claim 1 or 2 characterized by a fullerene thin film being a thin film which consists of a carbon cluster C60 and/or a carbon cluster C70.
[Claim 4] The semiconductor device according to claim 1 to 3 characterized by being one or more sorts chosen from the group which a fullerene thin film becomes from the vacuum deposition film, the cast film, and the polymer distribution film.
[Claim 5] The semiconductor device according to claim 1 to 4 to which an aluminum electrode is characterized by having an aluminum oxide layer in an interface with a fullerene thin film.
[Claim 6] The semiconductor device according to claim 1 to 5 to which an electrode is characterized by being a gap electrode or a sandwiches electrode.
[Claim 7] The semiconductor device according to claim 1 to 6 to which a semiconductor device is characterized by being a rectifying device.
[Claim 8] The semiconductor device according to claim 1 to 6 to which a semiconductor device is characterized by being a photosensor.

[Translation done.]

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DETAILED DESCRIPTION

[Detailed Description of the Invention]
[0001]
[Industrial Application] Especially this invention relates to the semiconductor device which has the outstanding rectifying action and the outstanding photoconductivity with respect to an organic-semiconductor component.
[0002]
[Description of the Prior Art] In the field of a semiconductor device, inorganic substances, such as sulfuration cadmium NIUMU, a zinc oxide, crystal silicon, an amorphous silicon, and gallium arsenide, have been used conventionally. These are used for a transistor, a rectifying device, IC and LSI, the photosensor, the solar battery, etc. However, in order to produce a semiconductor device using these inorganic substances, it was what advanced vacuum devices, an advanced film production technique, advanced purity regulation, etc. are required, and cannot be released easily.
[0003] On the other hand, the versatility of the organic substance, semi-conductor nature, etc. began to attract attention, and great research has been made about the semi-conductor nature of organic compounds, such as polyacethylene, polypyrrole, and a phthalocyanine, and conductivity ("new and a conductive polymer", **** Hiroyuki editorial supervision, CMC, (1987)). As a semiconductor device which comes to pinch a conductive polymer or an organic semiconductor with a metal especially Polyacethylene, the poly diacetylene, polypyrrole, alpha-sesquithienyl, MS component which comes to pinch semi-conductor thin films (S), such as a phthalocyanine, with a metal electrode (M), or many components, such as an MIS component which comes to pinch the thin film (I) of an insulator in between, are proposed ("Physics of Semiconductor Devices" --) 2nd(s) Edition, S.M.Sze, John Wiley & Sons, NY (1981), D.Fichou, F.Garnier et al., CHEMTRONICS, 1988 or 176 pages. These organic compounds show the semi-conductor nature of P type or N type, and when it pinches with the small electrode of a work function, and the large electrode of a work function, they show a rectifying action. For example, in the case of alpha-sesquithienyl (D. Fichou, F.Garnier et al., CHEMTRONICS, 1988 or 176 pages), when this is pinched with aluminum and an indium-tin-oxide (or gold) electrode, **1V show the rectifying action of 100 times or more. Furthermore, the example (Pt| polypyrrole | poly thiophene |In, M.Aizawa, H.Shirakawa, Synth.Met., No. 18, and 711 pages (1987)) which built the rectifying device, and the example (H. Koezuka, et al., Synth.Met., No. 18, and 699 pages (1987)) which built FET are also known for junction of a different-species conductive polymer. Moreover, a phthalocyanine etc. shows a photoconductivity, the application to a solar battery etc. is considered, and the solar battery pinched with aluminum and ITO glass (electrically conductive glass by the indium oxide - tin-oxide thin film) is examined.
[0004]
[Problem(s) to be Solved by the Invention] the above-mentioned organic compound -- general -- the instability (the air in polyacethylene --) of S layers, i.e., a conductive polymer layer, or an organic-semiconductor layer the fall (alpha-sesquithienyl --) of repeatability by mixing of an impurity, such as instability over humidity etc., and instability after doping A phthalocyanine etc. does not have the solvent which dissolves only concentrated-sulfuric-acid extent, and

improvement in purity is very difficult for it. Indeterminacy at the time of component formation (mixing of the catalyst by the vapor phase polymerization, electrolytic polymerization, etc., an electrolyte, etc.) Mixing of the impurity by the pyrolysis at the time of vacuum deposition, such as alpha-sesquithienyl and a phthalocyanine, Neither has resulted in utilization by the corrosion (corrosion of the electrode by the dopant, promotion of oxidization of an aluminum electrode which is looked at by the phthalocyanine, etc.) of the electrode after component formation, the mechanical brittleness (if vacuum deposition film, such as alpha-sesquithienyl and a phthalocyanine, is rubbed, it will separate) of a thin film, etc. Furthermore in a solar battery, it has not resulted [from the lowness of conversion efficiency] in the degradation with the passage of time and utilization. It is electrophotography photo conductor extent using the polymer battery which used the poly aniline, the capacitor using TCNQ, a phthalocyanine, etc. which was slightly put in practical use with the organic substance, and the present condition is that an outstanding result cannot be found.

[0005]

[Means for Solving the Problem] this invention persons take an example by the various faults like the above of organic semiconductors including the conventional conductive polymer. As a result of inquiring wholeheartedly that these should be improved, a fullerene thin film is used. While forming from one or more sorts of ingredients chosen from the group which prepares two or more electrodes so that this may be touched, and consists this electrode of platinum, gold, silver, copper, aluminum, an indium, the tin oxide, indium oxide, a zinc oxide, and carbon By using the at least one electrode as an aluminum electrode, a semiconductor device is easily obtained with sufficient repeatability, and it finds out that said technical problem is also solvable, and came to complete this invention.

[0006] That is, this invention comes to have two or more electrodes which consist of one or more sorts of ingredients chosen from the group which consists of the platinum and gold which touch a fullerene thin film and this, silver, copper, aluminum, an indium, the tin oxide, indium oxide, a zinc oxide, and carbon, and at least one electrode offers the semiconductor device characterized by being an aluminum electrode.

[0007] Hereafter, this invention is explained in detail. The fullerene thin film used by this invention is a thin film formed using fullerene. here, it becomes fullerene from sp2 carbon -- it is the generic name of the carbon cluster of the shape of spherical or a Rugby ball, and, generally C60, C70, C76, C78, and C84 grade are known. These contain carbon in arc discharge or the middle class of soot which carry out resistance heating, and it was made to evaporate, it quenched with inert gas, such as helium, and was generated, and C60 (for example, Nature(s), such as Kraetschmer, No. 347, 354 etc. pages (1990), etc.) contains them. [most] And the mixture of the above-mentioned carbon cluster is obtained from this soot by extracting, for example with solvents, such as a hexane, benzene, toluene, a mesitylene, and a carbon disulfide. for refining this mixture furthermore and isolating respectively -- usually -- purification of an organic compound -- business -- **** -- a chromatography -- technique (for example, Nature (s), such as Kraetschmer, No. 347, 354 etc. pages (1990), etc.) can be used. In this invention, the mixed fullerene by which composition and isolation perform extract and insoluble impurity removal, and are acquired from the soot containing C60 or C70, or these is used preferably.

[easy]

[0008] A fullerene thin film can be formed by various kinds of film production approaches, and can be used, for example, the vacuum deposition film, the cast film, the polymer distribution film, etc. can be used. According to the technique of general vacuum deposition, fullerene is heated under the vacuum of 5x10 to 5 or less torrs using a metallicity boat or an alumina nature boat (the volume thin film handbooks and for 131st committee of the Japan Society for the Promotion of Science thin film, Ohm-Sha (1984), etc.), and the vacuum deposition film can form a thin film by putting a substrate on the upper part or lower part. Under the present circumstances, the need may be accepted, and a substrate may be heated or cooled. When a thin film is amorphous when a substrate is cooled, and it heats more than a room temperature or it, it is obtained as a crystallized state. The vacuum deposition film of these fullerene is very firmly [stably] firm in air. For example, the conventional phthalocyanine, alpha-sesquithienyl, etc. will separate, if it

rubs, and to being inferior to a mechanical strength so that it can exfoliate easily with a Scotch tape etc., even if it rubs the vacuum evaporationo film of fullerene, it does not separate easily, but it is firm film which cannot exfoliate and is excellent in a Scotch tape at a mechanical strength.

[0009] The cast film is the means which uses the property which for example, fullerene dissolves in aromatic hydrocarbon, such as benzene, toluene, and a mesitylene, a carbon disulfide, n-hexane, etc., and can create a thin film simple. Namely, make it dissolve in the above-mentioned solvent etc., and it is dropped on a substrate, or a substrate is fixed on a spinner. After the above-mentioned solution is dropped, make it rotate at a suitable rotational frequency, and thin-film-ize a spinner. Or with the means of thin-film-izing the solution dropped on the substrate using a bar coating machine or a doctor blade, it can thin-film-ize and, subsequently a film can be produced air drying, heat, or by drying with means, such as carrying out a vacuum drying.

[0010] The polymer distribution film can be produced with the same means as the above-mentioned cast film, after adding fullerene in the solution of a polymer and making it dissolve or distribute. As the distributed approach, the pigment-content powder technique, such as a paint shaker, a spec. SUMIKI sir mill, a sand mill, a ball mill, ATORATA, and a kneader, can be used. As a polymer which can be used here, although there is especially no limit, when an example is given, there are copolymers, such as fluorination polymers, such as vinyl system polymers, such as saturated polyester, unsaturated polyester, a polycarbonate, a polyvinyl chloride, Pori acetic-acid vinyl, a poly vinyl carbazole, and styrene, fluoride poly vinylidene, and fluoride polyvinyl, and a styrene maleic acid, etc. Moreover, for example, liquid crystal macromolecules, such as a polyacrylate system liquid crystal macromolecule and a polysiloxane system liquid crystal macromolecule, can also be used.

[0011] In order to pull out the semi-conductor nature which was excellent in fullerene, it is required to prepare two or more electrodes which touch a fullerene thin film. What consists of one or more sorts of ingredients chosen from the small aluminum of a work function or the large platinum of a work function, gold, silver, copper, an indium, the tin oxide (for example, Nesa glass), indium oxide, indium oxide - the tin oxide (for example, ITO glass), a zinc oxide, and carbon (graphite, glassy carbon) as an electrode is used, and let especially at least one of the electrodes of these be an aluminum electrode. When using as a semiconductor device especially a transistor, a rectifying device, etc., it is necessary to prepare the small electrode of the above-mentioned work function, and the large electrode of a work function. However, if an aluminum electrode is used, especially, a semiconductor device can show a bidirectional rectifying action and can use it as a bidirectional switching element, a bidirectional rectifying device, etc. Furthermore, if this electrode is put to air after forming an aluminum electrode, a very thin aluminum oxide layer will be formed in a front face. The component of this invention constituted by forming a fullerene thin film besides and subsequently forming the electrode of arbitration also shows a higher rectification ratio, and will become still more desirable as a rectifying device. Moreover, also when using as a photosensor, a big photocurrent can be acquired by using what was mentioned above as an electrode and using aluminum for each other electrode or one electrode. Especially with the component which formed and obtained the aluminum oxide layer to the interface of an electrode and a fullerene thin film like the above, a still bigger photocurrent can be acquired and it will become desirable.

[0012] A metal plate, a carbon plate, a thin film, the conductive paint film, etc. can be used for an electrode with any gestalt. When using it with the gestalt of a thin film, it can be used with the means of a metallic foil, the vacuum evaporationo film, the sputtering film, an electrodeposited film, the spray pyrolysis film, etc., thin-film-izing. Moreover, a conductive paint (for example, silver, a carbon content coating) can be applied, and an electrode can also be formed. Here, when preparing an electrode by film production or spreading, a semiconductor device is preferably formed using a substrate. As this substrate, there is especially no limit and it should just be an insulating thing. Moreover, especially when using tabular electrodes, such as a metal plate and a carbon plate, it is not necessary to use a substrate.

[0013] As a configuration of an electrode, gap electrodes, such as a parallel pole or a gear-tooth electrode of a comb, or the sandwiches electrode prepared so that a fullerene thin film may be

pinched can be used, for example. Thickness of an electrode can be made arbitrary, when using it as a semiconductor device, especially a rectifying device, or when using it as a photosensor with a gap electrode. Moreover, although especially a limit does not have the gap width of face of a gap electrode, since a current will become small if gap width of face is large, the gap of 1mm or less is desirable. Moreover, since a current value becomes [the longer one] large and a big response is obtained, gap length is suitable. Also in a gap electrode, if the gear-tooth electrode of a comb is used, since gap length can do it still longer, it is more desirable. On the other hand, when using it as a photosensor with a sandwiches electrode, the electrode of the side which carries out incidence of the light needs to be translucent. Although the range whose permeability of light is 98% - 0.1% is used when using an oxide electrode, the responsibility over light has the high one where the permeability of light is larger. In the case of a metal electrode, the responsibility over light has the high one where the permeability of light is larger, but if permeability is too large, an electrode will not conduct a current. Therefore, as for the permeability of light, 50% - 0.1% of range is used suitably.

[0014] Moreover, about the thickness of the fullerene thin film which constitutes a semiconductor device, when using a gap electrode, that there should just be thickness of at least 1 molecule, it can use in 10A - 100 micrometers, and especially the range of 10A - 10 micrometers is used especially suitably. Since each other electrode will short-circuit if too thin when using a sandwiches electrode, a certain amount of thickness is required. In this case, the range of 100A - 100 micrometers is suitable for the thickness of a fullerene thin film, and it is especially formed in 200A - 10 micrometers preferably.

[0015] The semiconductor device of this invention constituted using a fullerene thin film and an electrode which were explained above is explained using a drawing. Each drawing 1 -4 shows an example of the semiconductor device of this invention. Each of drawing 1 and drawing 2 is what showed an example of a semiconductor device and a circuit which used the gap electrode, and it is the sectional view where (a) meets a top view and (b) meets the A-A line in (a). For an insulating substrate, 2a, and 2b, as for a fullerene thin film and 4, an electrode and 3 are [the sign 1 in drawing / DC power supply and 5] ammeters. The semiconductor device shown in drawing 1 is prepared so that gear-tooth electrode 2a of two combs and 2b may have few gaps and may gear on an insulating substrate 1, and the fullerene thin film 3 is further formed in the top face. Moreover, electrode 2a and 2b are connected through DC power supply 4 and an ammeter 5. Furthermore, protective coats, such as wrap insulation polymer film or an insulating metallic oxide, can also be formed for the fullerene thin film 3 if needed. Or the fullerene thin film 3 can be formed on an insulating substrate 1 like drawing 2 (b), and it can also consider as the configuration which prepared gear-tooth electrode 2a of a comb, and 2b in the top face further. The semiconductor device using such a gap electrode can be suitably used as a photosensor, it is in the condition which impressed electric field to electrode 2a and 2b from the power source 4, and if light is irradiated by the fullerene thin film 3, the current value between electrode 2a and 2b will change. This amount of current value changes is detected by the ammeter 5, and can measure the optical reinforcement irradiated based on this.

[0016] The semiconductor device of this invention which used the gap electrode for drawing 2 , and other examples of a circuit are shown. The fullerene thin film 3 is formed on an insulating substrate 1, and, as for the semiconductor device of this example, two parallel-pole 2a and 2bs are prepared in that top face. Furthermore, protective coats, such as wrap insulation polymer film or an insulating metallic oxide, can also be formed for electrode 2a, 2b, and the fullerene thin film 3 if needed. Or parallel-pole 2a and 2b can be prepared on an insulating substrate 1 like drawing 1 (b), and it can also consider as the configuration in which the fullerene thin film 3 was formed on the top face.

[0017] Drawing 3 and drawing 4 are what showed the example of the semiconductor device which used the sandwiches electrode, and it is the sectional view where (a) meets a top view and (b) meets the A-A line in (a). The 1st three electrode 2a, 2a, and 2a with which the semiconductor device shown in drawing 3 was formed in the shape of a strip of paper on the insulating substrate 1 is formed in parallel. It is prepared so that the 1st electrode 2a, 2a, and 2a of the above, and 2nd three electrode 2b, 2b and 2b which the fullerene thin film 3 was formed in

the insulating substrate 1 and the top face of these 1st electrodes 2a, 2a, and 2a, and were further formed in the shape of a strip of paper on this fullerene thin film 3 may cross at right angles in parallel. Furthermore, protective coats, such as wrap insulation polymer film or an insulating metallic oxide, can also be formed for the 2nd electrode 2b, 2b, 2b, and fullerene thin film 3 if needed. Here, the number of the 1st electrode and the 2nd electrodes is set as the number of one or more arbitration, respectively, and can carry out things. The semiconductor device using such a sandwiches electrode is used suitable for the integrated rectifying devices (for example, switching element etc.), for example, can drive liquid crystal, ECD, etc. Or it is suitably used also as photosensors (for example, image sensors etc.). Electric field can be impressed to the 1st electrode and 2nd electrode which go direct mutually from an outdrive unit (not shown) in these cases, and it can use as a rectifying device or a photosensor.

[0018] Drawing 4 shows other examples of the semiconductor device of this invention which used the sandwiches electrode. 2nd electrode 2b is prepared on an insulating substrate 1, all over the this insulating-substrate 1 and 2nd electrode 2b top, the fullerene thin film 3 is formed and, as for this thing, the 1st electrode 2a, 2a, and 2a formed in the shape of a strip of paper on the fullerene thin film 3 is formed further. The number of these 1st electrode 2a is set as the number of one or more arbitration, and can carry out things. In addition, what kind of configurations, such as not only the shape of a strip of paper but a circle, an ellipse, etc., are sufficient as 1st electrode 2a. 2nd electrode 2b leaves one edge section 1a of substrate 1 top face, and is formed in band-like [thick]. Moreover, the 1st electrode 2a, 2a, and 2a It intersects perpendicularly with the longitudinal direction of 2nd electrode 2b formed previously, it is prepared so that it may be crossed and located on edge section 1a of the above-mentioned insulating substrate 1 from on 2nd [of a parenthesis] electrode 2b, and it can prevent un-arranging [which wiring from the 1st electrode and 2nd electrode short-circuits by this]. Moreover, protective coats, such as insulating polymer film or an insulating metallic oxide, can also be formed if needed on the 1st electrode 2a, 2a, and 2a and the fullerene thin film 3. Thus, the constituted semiconductor device can be used effective in an independent rectifying device, a transistor, a photosensor, etc.

[0019] In addition, the semiconductor device of this invention is not limited to the configuration of the above-mentioned example, and various gestalten are possible for it and it may consist of a crystal, powder, etc. Furthermore, various gestalten can be taken by the purpose of using a semi-conductor, and based on these purposes, the configuration of an electrode and a component is changed suitably and it deals in it.

[0020]

[Example] (Example 1 of reference)

The semiconductor device which has the configuration shown in drawing 1 was produced. On slide glass 1, gear-tooth electrode 2a of a comb with gap width of face of 0.10mm, ten electrode overlap, and an electrode overall length of 50mm and 2b were formed with vacuum deposition. Gold was used for electrode 2a and 2b, and it stuck to the thickness of 500A under the vacuum of 5x10-5torr. The slide glass 1 in which this electrode 2a and 2b were formed was put on 20cm on the alumina crucible of a vacuum deposition machine, and it vapor-deposited, having put the carbon cluster C60 into the crucible made from an alumina, and heating at 520-550 degrees C under the vacuum of 5x10-6torr (5A/(second)), the vacuum deposition film 3 of C60 was stuck to the thickness of 300A, and the semiconductor device was produced. They are wavelength;400nm and optical on-the-strength;7 mW/cm2, impressing the electric field of 10V to this component. When the homogeneous light was irradiated, the photocurrent of 55pA was detected. It is optical reinforcement 0.1, 0.5, 1.0 and 2.0, and 5.0 mW/cm2 When it was made to change, the photocurrent also increased along with the increment in optical reinforcement. Subsequently, although this component was left for one month in atmospheric air, it was changeless to a photocurrent. Moreover, although the Scotch tape was stretched on the vacuum deposition film of C60 and subsequently being removed, C60 vacuum-deposition film has arrived at the substrate firmly, and did not separate. Furthermore, although the epoxy resin performed the protection coat on the front face of this component, it was almost changeless to a photocurrent. Therefore, the component obtained in this example of reference had the engine

performance which was excellent as a photosensor.
[0021] (Example 1 of a comparison)
Like the above-mentioned example 1 of reference, on electrode 2a formed on slide glass 1, and 2b, vacuum deposition of the non-metal phthalocyanine was similarly carried out instead of the carbon cluster C60, and the thin film 3 was formed. When the same homogeneous light as the example 1 of reference was irradiated, the photocurrent of 15nA was observed. However, when this component was left for one month in atmospheric air, the photocurrent fell clearly. Moreover, when the Scotch tape was stuck and having been stripped on the non-metal phthalocyanine vacuum evaporationo film, the thin film of a non-metal phthalocyanine peeled altogether with the Scotch tape. Furthermore, when a protection coat is carried out with an epoxy resin, most photocurrents are no longer observed by the fatal thing.
[0022] (Example 1)
In the example 1 of reference, the semiconductor device was similarly produced as electrode 2a and 2b except using aluminum instead of gold. When the homogeneous light as well as the example 1 of reference was irradiated, the photocurrent of 600pA was observed. The photocurrent was observed even if it changed the wavelength of the homogeneous light with 300,500,600,700nm. Therefore, it was admitted that this component could detect a photocurrent in a visible region from ultraviolet. Furthermore, when applied voltage was set to 100V, it was admitted by a photocurrent's becoming 10 times and impressing large electric field that an optical large response was obtained.
[0023]
[0024] (Example 2)
The semiconductor device was produced in the above-mentioned example 1, using the cast film as a fullerene thin film 3. Like the example 1, using the spinner, the liquid made to dissolve the carbon cluster C60 in toluene was dropped, the cast film 3 of C60 was produced, the vacuum drying was carried out and the semiconductor device was produced at 100 more degrees C for 1 hour on electrode 2a which vapor-deposited aluminum on slide glass 1, and 2b. 1V are impressed to this component and they are 400nm and 5 mW/cm2. When the homogeneous light was irradiated, the photocurrent of 425pA was observed.
[0025] (Example 3)
The semiconductor device which has the configuration shown in drawing 4 was produced. Width of face of 0.5cm and die length of 3cm were etched with the hydrochloric acid on 3cm 2cmx indium tin glass (ITO glass) 1, the conductive film was removed (part equivalent to 1in drawing 4 a), and the conductive remaining film was made into indium oxide (ITO) electrode 2b. On this electrode 2b, the polymer distribution film 3 of C60 was produced for the dispersion liquid (60; 20mg of C, vinyl acetate;20mg, ethyl acetate; dispersion liquid which put the glass bead into 200mg and were distributed with the paint shaker for 1 hour) which made vinyl acetate / ethyl-acetate solution distribute C60 using bar coating-machine #10. The vacuum drying of this film 3 was carried out at 100 degrees C for 1 hour. Thickness was 1 micrometer. Subsequently, aluminum (width-of-face [of 0.5cm], die length of 1.5cm) electrode 2a was formed with three pieces and vacuum deposition on this film 3. From the function generator, the triangular wave of -2V to +2V was impressed at a scanning speed of 0.001Hz between this indium oxide electrode 2b and aluminum electrode 2a. The current-voltage characteristic at this time was shown in drawing 5 . The rectifying action was shown so that clearly from drawing 5 . On this component, although 3 sets of electrodes were formed, the repeatability was good. Moreover, even if it carried out the protection coat of the whole with the epoxy resin, the current-voltage characteristic hardly changed. Therefore, it was admitted that this component was an outstanding rectifying device.
[0026] (Example 4)
In the above-mentioned example 3, except having replaced with the indium oxide electrode and having prepared tin-oxide electrode 2b by using NESA glass instead of ITO glass, when the semiconductor device was produced similarly, this thing showed the good rectifying action like the thing of an example 3.
[0027] (Example 2 of a comparison)

In the above-mentioned example 3, the semiconductor device was similarly formed except using a non-metal phthalocyanine instead of C60. Also in this case, the rectifying action was shown similarly. However, when a protection coat was carried out with an epoxy resin, the rectifying action decreased greatly.

[0028] (Example 5)

The semiconductor device which has the configuration shown in drawing 4 was produced. Up 0.5mmx3cm of the 2cmx3cm glass substrate 1 was covered, and on this substrate 1, vacuum deposition of the aluminum was carried out to the thickness of a 200 ONGUSU toe ROM, and it considered as electrode 2b (permeability of the 400nm homogeneous light; 2.18%). Furthermore, on this, vacuum deposition of C60 was carried out to 1000A thickness like the example 1 of reference, and the vacuum deposition film 3 of C60 was formed. Subsequently, on it, vacuum deposition of the two a3 0.5cmx1.5cm aluminum electrodes was carried out, and the semiconductor device was formed. When the triangular wave which is -1V to +1V was impressed to this component from the function generator (scanning speed; 0.002Hz), the current-voltage characteristic showed the bidirectional rectifying action as shown in drawing 6 . Moreover, repeatability was good about three electrodes.

[0029] (Example 3 of a comparison)

2000A of alpha-sesquithienyls was vapor-deposited on the top face of the glass plate 1 in which aluminum electrode 2b was formed, like the example 5 (20A/(second)). If it is very hard to vapor-deposit alpha-sesquithienyl and it is vapor-deposited slowly, it will serve as film which decomposed and contained many impurities. Although decomposition will decrease if it vapor-deposits quickly (20A/(second) or more), an impurity is contained too. Subsequently, 0.5cmx1.5cm aluminum electrode 2a was prepared by three-piece vacuum evaporationo. The triangular wave of -2 to +2V was impressed to this component from the function generator (0.002Hz). This component showed a rectifying action, or did not show it, and its repeatability was very bad.

[0030] (Example 6)

The homogeneous light of wavelength;400nm and on-the-strength;700 microwatt/cm 2 was irradiated from the glass plate 1 side at the electrode, impressing 0.1V to aluminum electrode 2a of the semiconductor device obtained in the example 5, and 2b. The photocurrent of 535nA was observed at this time. When changing the wavelength of exposure light, the photocurrent has been observed to the 800nm homogeneous light. Moreover, by the homogeneous light with a wavelength of 400nm, when changing optical reinforcement, the photocurrent also increased according to exposure light reinforcement. Moreover, repeatability was good about three electrodes.

[0031] (Example 7)

The semiconductor device which has the configuration shown in drawing 4 was produced. Up 0.5mmx3cm of the 2cmx3cm glass substrate 1 was covered, on this substrate 1, platinum was stuck by sputtering and platinum-electrode 2b was formed. Subsequently, the polycarbonate polymer distribution film 3 of C60 was formed with the spinner, and it dried. Subsequently, aluminum electrode 2a was formed with vacuum deposition. The rectifying action was observed when the triangular wave of +1V was impressed from -1 like the example 5.

[0032] (Example 8)

When the platinum vacuum evaporationo film was replaced with the carbon-shadowing film in the above-mentioned example 7 and carbon-electrode 2b was prepared, the rectifying action was shown similarly.

[0033] (Example 9)

In the above-mentioned example 5, except using C70 instead of C60, similarly, when the semiconductor device was obtained and measured, the current-voltage characteristic showed the same bidirectional rectifying characteristic.

[0034] (Example 10)

In the example 7, silver electrode 2b was formed with vacuum deposition instead of the platinum electrode. This component showed the rectifying action like drawing 5 similarly. Moreover, the photocurrent was observed when on-the-strength 1 mW/cm2 and the 450nm homogeneous light

were irradiated from an aluminum electrode side.
[0035] (Example 11)
In the example 7, copper-electrode 2b was formed with vacuum deposition instead of the platinum electrode. This component showed the rectifying action like drawing 5 similarly. Moreover, the photocurrent was observed when on-the-strength 1 mW/cm2 and the 450nm homogeneous light were irradiated from an aluminum electrode side.
[0036] (Example 12)
In the example 3, instead of ITO glass and an indium oxide electrode, when others were performed like the example 3 using what formed zinc-oxide electrode 2b by sputtering on the glass substrate 1, the same rectifying action was observed.
[0037] (Example 13)
The same component as an example 5 was formed. First, after forming aluminum electrode 2b on a substrate, it once took out in air and was left under the room temperature for 24 hours. Then, it put in in the vacuum evaporation system, vacuum deposition of C60 was carried out to 1000A thickness like the example 5, and the vacuum deposition film 3 of C60 was formed. Then, two pieces were vapor-deposited for 0.5cmx1.5cm aluminum electrode 2a, one piece was vapor-deposited for the golden electrode, respectively, and the semiconductor device was formed. The permeability of electrode 2a (aluminum, gold) and 400nm homogeneous light of 2b was 2%. After component formation, also when the current-voltage characteristic of -1-+1V was measured immediately, and electrode 2a was any of aluminum and gold, a rectifying characteristic like drawing 5 was shown. Moreover, when 1V were impressed between electrode 2a and 2b, 2 was irradiated at aluminum electrode 2b and the homogeneous light was irradiated at the wavelength of 400nm on the strength of 5mW/cm, as compared with the time of irradiating the same light as aluminum electrode 2a or golden electrode 2a, the about 25 times as many photocurrent as this was observed. When argon etching of this component was carried out from the electrode 2a side using ESCA and the presentation of the membranous thickness direction was analyzed, it was admitted that the aluminum oxide existed in the interface of C60 film 3 and aluminum electrode 2b.
[0038] (Example 2 of reference)
Commercial crude soot was refined and C60 and C70 were obtained. First, 4g (vacuum metallurgy incorporated company make) of crude soot containing fullerene was put into the extraction thimble, and it extracted by n-hexane;200ml for 24 hours using the Soxhlet extractor. Subsequently, the solvent was changed into mesitylene;200ml and the extract was performed for further 24 hours. When the first n-hexane solution was analyzed by liquid chromatography (silica gel - n-hexane), the ratio of C60:C70 is 9:1 and did not contain most of 70 or more C fullerene. The ratio of C60:C70 is about 6:4, and the mesitylene extract was carrying out variety content of the 70 or more C fullerene. n-hexane extract was condensed by the evaporator and 0.26g fullerene mixture was obtained. Using the ODS column, the mixed solvent of a 2-propanol / toluene;6/4 was used as the developing solution, and 0.21g and 0.02g of high grades C70 were obtained for the high grade C60 using inside low voltage preparative chromatograph. The mesitylene extract was condensed by the evaporator and mixed fullerene 0.13g was obtained. It isolated preparatively by the chromatograph similarly and mixture;0.01g of 60; 0.07g of high grades C, 70; 0.04g of high grades C, and other fullerene was obtained. Mixture contained C76, C78, C84, and fullerene with still larger molecular weight from GC-MS analysis.
[0039]
[Effect of the Invention] As explained above, the semiconductor device of this invention comes to have two or more electrodes which touch a fullerene thin film and this, and at least one electrode consists of small aluminum electrodes of a work function. Therefore, when especially two electrodes consist of aluminum, a bidirectional rectifying action can be shown and it can be used as a bidirectional switching element, a bidirectional rectifying device, etc. moreover, when a very thin aluminum oxide layer is formed in the aluminum electrode surface which touches C60 interface A bigger photocurrent can be acquired, also when a higher rectification ratio is shown and it uses as a photosensor further (for example, in the example 1, photocurrent 600pA of 10 times or more was obtained [photocurrent 55pA obtained when gold was used for the two

electrodes made into the example 1 of reference].). The outstanding engine performance is shown. Moreover, this semiconductor device shows semi-conductor nature especially a rectifying action, and a photoconductivity. And fullerene is easy to compound, and in order to dissolve in a solvent, it is easy to refine, and it can obtain a high grade article easily. Moreover, thermal resistance is also high, since the decomposition at the time of vacuum evaporationo does not take place, either, component-izing is easy and a property with sufficient repeatability is acquired. Moreover, it can be used also in the form of the cast film which does not need a vacuum, and the polymer distribution film. Therefore, the semiconductor device which is rich in stability and repeatability can be easily constituted by using the fullerene thin film which produces fullerene and is obtained. Furthermore, since the engine performance does not change even if it gives the protection coat which used resin etc., the semiconductor device of this invention can be used for an extensive application. Especially, it is broadly applicable to driver elements, such as a rectifying device, liquid crystal using a rectifying action, and an ECD component, a photosensor, or the image sensors adapting a photosensor function.

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TECHNICAL FIELD

[Industrial Application] Especially this invention relates to the semiconductor device which has the outstanding rectifying action and the outstanding photoconductivity with respect to an organic-semiconductor component.

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PRIOR ART

[Description of the Prior Art] In the field of a semiconductor device, inorganic substances, such as sulfuration cadmium NIUMU, a zinc oxide, crystal silicon, an amorphous silicon, and gallium arsenide, have been used conventionally. These are used for a transistor, a rectifying device, IC and LSI, the photosensor, the solar battery, etc. However, in order to produce a semiconductor device using these inorganic substances, it was what advanced vacuum devices, an advanced film production technique, advanced purity regulation, etc. are required, and cannot be released easily.
[0003] On the other hand, the versatility of the organic substance, semi-conductor nature, etc. began to attract attention, and great research has been made about the semi-conductor nature of organic compounds, such as polyacethylene, polypyrrole, and a phthalocyanine, and conductivity ("new and a conductive polymer", **** Hiroyuki editorial supervision, CMC, (1987)). As a semiconductor device which comes to pinch a conductive polymer or an organic semiconductor with a metal especially Polyacethylene, the poly diacetylene, polypyrrole, alpha-sesquithienyl, MS component which comes to pinch semi-conductor thin films (S), such as a phthalocyanine, with a metal electrode (M), or many components, such as an MIS component which comes to pinch the thin film (I) of an insulator in between, are proposed ("Physics of Semiconductor Devices" --) 2nd(s) Edition, S.M.Sze, John Wiley & Sons, NY (1981), D.Fichou, F.Garnier et al., CHEMTRONICS, 1988 or 176 pages. These organic compounds show the semi-conductor nature of P type or N type, and when it pinches with the small electrode of a work function, and the large electrode of a work function, they show a rectifying action. For example, in the case of alpha-sesquithienyl (D. Fichou, F.Garnier et al., CHEMTRONICS, 1988 or 176 pages), when this is pinched with aluminum and an indium-tin-oxide (or gold) electrode, **1V show the rectifying action of 100 times or more. Furthermore, the example (Pt| polypyrrole | poly thiophene |In, M.Aizawa, H.Shirakawa, Synth.Met., No. 18, and 711 pages (1987)) which built the rectifying device, and the example (H. Koezuka, et al., Synth.Met., No. 18, and 699 pages (1987)) which built FET are also known for junction of a different-species conductive polymer. Moreover, a phthalocyanine etc. shows a photoconductivity, the application to a solar battery etc. is considered, and the solar battery pinched with aluminum and ITO glass (electrically conductive glass by the indium oxide - tin-oxide thin film) is examined.

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EFFECT OF THE INVENTION

[Effect of the Invention] As explained above, the semiconductor device of this invention comes to have two or more electrodes which touch a fullerene thin film and this, and at least one electrode consists of small aluminum electrodes of a work function. Therefore, when especially two electrodes consist of aluminum, a bidirectional rectifying action can be shown and it can be used as a bidirectional switching element, a bidirectional rectifying device, etc. moreover, when a very thin aluminum oxide layer is formed in the aluminum electrode surface which touches C60 interface A bigger photocurrent can be acquired, also when a higher rectification ratio is shown and it uses as a photosensor further (for example, in the example 1, photocurrent 600pA of 10 times or more was obtained [photocurrent 55pA obtained when gold was used for the two electrodes made into the example 1 of reference].). The outstanding engine performance is shown. Moreover, this semiconductor device shows semi-conductor nature especially a rectifying action, and a photoconductivity. And fullerene is easy to compound, and in order to dissolve in a solvent, it is easy to refine, and it can obtain a high grade article easily. Moreover, thermal resistance is also high, since the decomposition at the time of vacuum evaporationo does not take place, either, component-izing is easy and a property with sufficient repeatability is acquired. Moreover, it can be used also in the form of the cast film which does not need a vacuum, and the polymer distribution film. Therefore, the semiconductor device which is rich in stability and repeatability can be easily constituted by using the fullerene thin film which produces fullerene and is obtained. Furthermore, since the engine performance does not change even if it gives the protection coat which used resin etc., the semiconductor device of this invention can be used for an extensive application. Especially, it is broadly applicable to driver elements, such as a rectifying device, liquid crystal using a rectifying action, and an ECD component, a photosensor, or the image sensors adapting a photosensor function.

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TECHNICAL PROBLEM

[Problem(s) to be Solved by the Invention] the above-mentioned organic compound -- general -- the instability (the air in polyacethylene --) of S layers, i.e., a conductive polymer layer, or an organic-semiconductor layer the fall (alpha-sesquithienyl --) of repeatability by mixing of an impurity, such as instability over humidity etc., and instability after doping A phthalocyanine etc. does not have the solvent which dissolves only concentrated-sulfuric-acid extent, and improvement in purity is very difficult for it. Indeterminacy at the time of component formation (mixing of the catalyst by the vapor phase polymerization, electrolytic polymerization, etc., an electrolyte, etc.) Mixing of the impurity by the pyrolysis at the time of vacuum deposition, such as alpha-sesquithienyl and a phthalocyanine, Neither has resulted in utilization by the corrosion (corrosion of the electrode by the dopant, promotion of oxidization of an aluminum electrode which is looked at by the phthalocyanine, etc.) of the electrode after component formation, the mechanical brittleness (if vacuum deposition film, such as alpha-sesquithienyl and a phthalocyanine, is rubbed, it will separate) of a thin film, etc. Furthermore in a solar battery, it has not resulted [from the lowness of conversion efficiency] in the degradation with the passage of time and utilization. It is electrophotography photo conductor extent using the polymer battery which used the poly aniline, the capacitor using TCNQ, a phthalocyanine, etc. which was slightly put in practical use with the organic substance, and the present condition is that an outstanding result cannot be found.

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MEANS

[Means for Solving the Problem] this invention persons take an example by the various faults like the above of organic semiconductors including the conventional conductive polymer. As a result of inquiring wholeheartedly that these should be improved, a fullerene thin film is used. While forming from one or more sorts of ingredients chosen from the group which prepares two or more electrodes so that this may be touched, and consists this electrode of platinum, gold, silver, copper, aluminum, an indium, the tin oxide, indium oxide, a zinc oxide, and carbon By using the at least one electrode as an aluminum electrode, a semiconductor device is easily obtained with sufficient repeatability, and it finds out that said technical problem is also solvable, and came to complete this invention.
[0006] That is, this invention comes to have two or more electrodes which consist of one or more sorts of ingredients chosen from the group which consists of the platinum and gold which touch a fullerene thin film and this, silver, copper, aluminum, an indium, the tin oxide, indium oxide, a zinc oxide, and carbon, and at least one electrode offers the semiconductor device characterized by being an aluminum electrode.
[0007] Hereafter, this invention is explained in detail. The fullerene thin film used by this invention is a thin film formed using fullerene. here, it becomes fullerene from sp2 carbon -- it is the generic name of the carbon cluster of the shape of spherical or a Rugby ball, and, generally C60, C70, C76, C78, and C84 grade are known. These contain carbon in arc discharge or the middle class of soot which carry out resistance heating, and it was made to evaporate, it quenched with inert gas, such as helium, and was generated, and C60 (for example, Nature(s), such as Kraetschmer, No. 347, 354 etc. pages (1990), etc.) contains them. [most] And the mixture of the above-mentioned carbon cluster is obtained from this soot by extracting, for example with solvents, such as a hexane, benzene, toluene, a mesitylene, and a carbon disulfide. for refining this mixture furthermore and isolating respectively -- usually -- purification of an organic compound -- business -- **** -- a chromatography -- technique (for example, Nature (s), such as Kraetschmer, No. 347, 354 etc. pages (1990), etc.) can be used. In this invention, the mixed fullerene by which composition and isolation perform extract and insoluble impurity removal, and are acquired from the soot containing C60 or C70, or these is used preferably. [easy]
[0008] A fullerene thin film can be formed by various kinds of film production approaches, and can be used, for example, the vacuum deposition film, the cast film, the polymer distribution film, etc. can be used. According to the technique of general vacuum deposition, fullerene is heated under the vacuum of 5x10 to 5 or less torrs using a metallicity boat or an alumina nature boat (the volume thin film handbooks and for 131st committee of the Japan Society for the Promotion of Science thin film, Ohm-Sha (1984), etc.), and the vacuum deposition film can form a thin film by putting a substrate on the upper part or lower part. Under the present circumstances, the need may be accepted, and a substrate may be heated or cooled. When a thin film is amorphous when a substrate is cooled, and it heats more than a room temperature or it, it is obtained as a crystallized state. The vacuum deposition film of these fullerene is very firmly [stably] firm in air. For example, the conventional phthalocyanine, alpha-sesquithienyl, etc. will separate, if it rubs, and to being inferior to a mechanical strength so that it can exfoliate easily with a Scotch

tape etc., even if it rubs the vacuum evaporationo film of fullerene, it does not separate easily, but it is firm film which cannot exfoliate and is excellent in a Scotch tape at a mechanical strength.

[0009] The cast film is the means which uses the property which for example, fullerene dissolves in aromatic hydrocarbon, such as benzene, toluene, and a mesitylene, a carbon disulfide, n-hexane, etc., and can create a thin film simple. Namely, make it dissolve in the above-mentioned solvent etc., and it is dropped on a substrate, or a substrate is fixed on a spinner. After the above-mentioned solution is dropped, make it rotate at a suitable rotational frequency, and thin-film-ize a spinner. Or with the means of thin-film-izing the solution dropped on the substrate using a bar coating machine or a doctor blade, it can thin-film-ize and, subsequently a film can be produced air drying, heat, or by drying with means, such as carrying out a vacuum drying.

[0010] The polymer distribution film can be produced with the same means as the above-mentioned cast film, after adding fullerene in the solution of a polymer and making it dissolve or distribute. As the distributed approach, the pigment-content powder technique, such as a paint shaker, a spec. SUMIKI sir mill, a sand mill, a ball mill, ATORATA, and a kneader, can be used. As a polymer which can be used here, although there is especially no limit, when an example is given, there are copolymers, such as fluorination polymers, such as vinyl system polymers, such as saturated polyester, unsaturated polyester, a polycarbonate, a polyvinyl chloride, Pori acetic-acid vinyl, a poly vinyl carbazole, and styrene, fluoride poly vinylidene, and fluoride polyvinyl, and a styrene maleic acid, etc. Moreover, for example, liquid crystal macromolecules, such as a polyacrylate system liquid crystal macromolecule and a polysiloxane system liquid crystal macromolecule, can also be used.

[0011] In order to pull out the semi-conductor nature which was excellent in fullerene, it is required to prepare two or more electrodes which touch a fullerene thin film. What consists of one or more sorts of ingredients chosen from the small aluminum of a work function or the large platinum of a work function, gold, silver, copper, an indium, the tin oxide (for example, Nesa glass), indium oxide, indium oxide - the tin oxide (for example, ITO glass), a zinc oxide, and carbon (graphite, glassy carbon) as an electrode is used, and let especially at least one of the electrodes of these be an aluminum electrode. When using as a semiconductor device especially a transistor, a rectifying device, etc., it is necessary to prepare the small electrode of the above-mentioned work function, and the large electrode of a work function. However, if an aluminum electrode is used, especially, a semiconductor device can show a bidirectional rectifying action and can use it as a bidirectional switching element, a bidirectional rectifying device, etc. Furthermore, if this electrode is put to air after forming an aluminum electrode, a very thin aluminum oxide layer will be formed in a front face. The component of this invention constituted by forming a fullerene thin film besides and subsequently forming the electrode of arbitration also shows a higher rectification ratio, and will become still more desirable as a rectifying device. Moreover, also when using as a photosensor, a big photocurrent can be acquired by using what was mentioned above as an electrode and using aluminum for each other electrode or one electrode. Especially with the component which formed and obtained the aluminum oxide layer to the interface of an electrode and a fullerene thin film like the above, a still bigger photocurrent can be acquired and it will become desirable.

[0012] A metal plate, a carbon plate, a thin film, the conductive paint film, etc. can be used for an electrode with any gestalt. When using it with the gestalt of a thin film, it can be used with the means of a metallic foil, the vacuum evaporationo film, the sputtering film, an electrodeposited film, the spray pyrolysis film, etc., thin-film-izing. Moreover, a conductive paint (for example, silver, a carbon content coating) can be applied, and an electrode can also be formed. Here, when preparing an electrode by film production or spreading, a semiconductor device is preferably formed using a substrate. As this substrate, there is especially no limit and it should just be an insulating thing. Moreover, especially when using tabular electrodes, such as a metal plate and a carbon plate, it is not necessary to use a substrate.

[0013] As a configuration of an electrode, gap electrodes, such as a parallel pole or a gear-tooth electrode of a comb, or the sandwiches electrode prepared so that a fullerene thin film may be pinched can be used, for example. Thickness of an electrode can be made arbitrary, when using

it as a semiconductor device, especially a rectifying device, or when using it as a photosensor with a gap electrode. Moreover, although especially a limit does not have the gap width of face of a gap electrode, since a current will become small if gap width of face is large, the gap of 1mm or less is desirable. Moreover, since a current value becomes [the longer one] large and a big response is obtained, gap length is suitable. Also in a gap electrode, if the gear-tooth electrode of a comb is used, since gap length can do it still longer, it is more desirable. On the other hand, when using it as a photosensor with a sandwiches electrode, the electrode of the side which carries out incidence of the light needs to be translucent. Although the range whose permeability of light is 98% - 0.1% is used when using an oxide electrode, the responsibility over light has the high one where the permeability of light is larger. In the case of a metal electrode, the responsibility over light has the high one where the permeability of light is larger, but if permeability is too large, an electrode will not conduct a current. Therefore, as for the permeability of light, 50% - 0.1% of range is used suitably.

[0014] Moreover, about the thickness of the fullerene thin film which constitutes a semiconductor device, when using a gap electrode, that there should just be thickness of at least 1 molecule, it can use in 10A - 100 micrometers, and especially the range of 10A - 10 micrometers is used especially suitably. Since each other electrode will short-circuit if too thin when using a sandwiches electrode, a certain amount of thickness is required. In this case, the range of 100A - 100 micrometers is suitable for the thickness of a fullerene thin film, and it is especially formed in 200A - 10 micrometers preferably.

[0015] The semiconductor device of this invention constituted using a fullerene thin film and an electrode which were explained above is explained using a drawing. Each drawing 1 -4 shows an example of the semiconductor device of this invention. Each of drawing 1 and drawing 2 is what showed an example of a semiconductor device and a circuit which used the gap electrode, and it is the sectional view where (a) meets a top view and (b) meets the A-A line in (a). For an insulating substrate, 2a, and 2b, as for a fullerene thin film and 4, an electrode and 3 are [the sign 1 in drawing / DC power supply and 5] ammeters. The semiconductor device shown in drawing 1 is prepared so that gear-tooth electrode 2a of two combs and 2b may have few gaps and may gear on an insulating substrate 1, and the fullerene thin film 3 is further formed in the top face. Moreover, electrode 2a and 2b are connected through DC power supply 4 and an ammeter 5. Furthermore, protective coats, such as wrap insulation polymer film or an insulating metallic oxide, can also be formed for the fullerene thin film 3 if needed. Or the fullerene thin film 3 can be formed on an insulating substrate 1 like drawing 2 (b), and it can also consider as the configuration which prepared gear-tooth electrode 2a of a comb, and 2b in the top face further. The semiconductor device using such a gap electrode can be suitably used as a photosensor, it is in the condition which impressed electric field to electrode 2a and 2b from the power source 4, and if light is irradiated by the fullerene thin film 3, the current value between electrode 2a and 2b will change. This amount of current value changes is detected by the ammeter 5, and can measure the optical reinforcement irradiated based on this.

[0016] The semiconductor device of this invention which used the gap electrode for drawing 2 , and other examples of a circuit are shown. The fullerene thin film 3 is formed on an insulating substrate 1, and, as for the semiconductor device of this example, two parallel-pole 2a and 2bs are prepared in that top face. Furthermore, protective coats, such as wrap insulation polymer film or an insulating metallic oxide, can also be formed for electrode 2a, 2b, and the fullerene thin film 3 if needed. Or parallel-pole 2a and 2b can be prepared on an insulating substrate 1 like drawing 1 (b), and it can also consider as the configuration in which the fullerene thin film 3 was formed on the top face.

[0017] Drawing 3 and drawing 4 are what showed the example of the semiconductor device which used the sandwiches electrode, and it is the sectional view where (a) meets a top view and (b) meets the A-A line in (a). The 1st three electrode 2a, 2a, and 2a with which the semiconductor device shown in drawing 3 was formed in the shape of a strip of paper on the insulating substrate 1 is formed in parallel. It is prepared so that the 1st electrode 2a, 2a, and 2a of the above, and 2nd three electrode 2b, 2b and 2b which the fullerene thin film 3 was formed in the insulating substrate 1 and the top face of these 1st electrodes 2a, 2a, and 2a, and were

further formed in the shape of a strip of paper on this fullerene thin film 3 may cross at right angles in parallel. Furthermore, protective coats, such as wrap insulation polymer film or an insulating metallic oxide, can also be formed for the 2nd electrode 2b, 2b, 2b, and fullerene thin film 3 if needed. Here, the number of the 1st electrode and the 2nd electrodes is set as the number of one or more arbitration, respectively, and can carry out things. The semiconductor device using such a sandwiches electrode is used suitable for the integrated rectifying devices (for example, switching element etc.), for example, can drive liquid crystal, ECD, etc. Or it is suitably used also as photosensors (for example, image sensors etc.). Electric field can be impressed to the 1st electrode and 2nd electrode which go direct mutually from an outdrive unit (not shown) in these cases, and it can use as a rectifying device or a photosensor.

[0018] Drawing 4 shows other examples of the semiconductor device of this invention which used the sandwiches electrode. 2nd electrode 2b is prepared on an insulating substrate 1, all over the this insulating-substrate 1 and 2nd electrode 2b top, the fullerene thin film 3 is formed and, as for this thing, the 1st electrode 2a, 2a, and 2a formed in the shape of a strip of paper on the fullerene thin film 3 is formed further. The number of these 1st electrode 2a is set as the number of one or more arbitration, and can carry out things. In addition, what kind of configurations, such as not only the shape of a strip of paper but a circle, an ellipse, etc., are sufficient as 1st electrode 2a. 2nd electrode 2b leaves one edge section 1a of substrate 1 top face, and is formed in band-like [thick]. Moreover, the 1st electrode 2a, 2a, and 2a It intersects perpendicularly with the longitudinal direction of 2nd electrode 2b formed previously, it is prepared so that it may be crossed and located on edge section 1a of the above-mentioned insulating substrate 1 from on 2nd [of a parenthesis] electrode 2b, and it can prevent un-arranging [which wiring from the 1st electrode and 2nd electrode short-circuits by this]. Moreover, protective coats, such as insulating polymer film or an insulating metallic oxide, can also be formed if needed on the 1st electrode 2a, 2a, and 2a and the fullerene thin film 3. Thus, the constituted semiconductor device can be used effective in an independent rectifying device, a transistor, a photosensor, etc.

[0019] In addition, the semiconductor device of this invention is not limited to the configuration of the above-mentioned example, and various gestalten are possible for it and it may consist of a crystal, powder, etc. Furthermore, various gestalten can be taken by the purpose of using a semi-conductor, and based on these purposes, the configuration of an electrode and a component is changed suitably and it deals in it.

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EXAMPLE

[Example] (Example 1 of reference)
The semiconductor device which has the configuration shown in drawing 1 was produced. On slide glass 1, gear-tooth electrode 2a of a comb with gap width of face of 0.10mm, ten electrode overlap, and an electrode overall length of 50mm and 2b were formed with vacuum deposition. Gold was used for electrode 2a and 2b, and it stuck to the thickness of 500A under the vacuum of 5x10-5torr. The slide glass 1 in which this electrode 2a and 2b were formed was put on 20cm on the alumina crucible of a vacuum deposition machine, and it vapor-deposited, having put the carbon cluster C60 into the crucible made from an alumina, and heating at 520-550 degrees C under the vacuum of 5x10-6torr (5A/(second)), the vacuum deposition film 3 of C60 was stuck to the thickness of 300A, and the semiconductor device was produced. They are wavelength;400nm and optical on-the-strength;7 mW/cm2, impressing the electric field of 10V to this component. When the homogeneous light was irradiated, the photocurrent of 55pA was detected. It is optical reinforcement 0.1, 0.5, 1.0 and 2.0, and 5.0 mW/cm2 When it was made to change, the photocurrent also increased along with the increment in optical reinforcement. Subsequently, although this component was left for one month in atmospheric air, it was changeless to a photocurrent. Moreover, although the Scotch tape was stretched on the vacuum deposition film of C60 and subsequently being removed, C60 vacuum-deposition film has arrived at the substrate firmly, and did not separate. Furthermore, although the epoxy resin performed the protection coat on the front face of this component, it was almost changeless to a photocurrent. Therefore, the component obtained in this example of reference had the engine performance which was excellent as a photosensor.
[0021] (Example 1 of a comparison)
Like the above-mentioned example 1 of reference, on electrode 2a formed on slide glass 1, and 2b, vacuum deposition of the non-metal phthalocyanine was similarly carried out instead of the carbon cluster C60, and the thin film 3 was formed. When the same homogeneous light as the example 1 of reference was irradiated, the photocurrent of 15nA was observed. However, when this component was left for one month in atmospheric air, the photocurrent fell clearly. Moreover, when the Scotch tape was stuck and having been stripped on the non-metal phthalocyanine vacuum evaporationo film, the thin film of a non-metal phthalocyanine peeled altogether with the Scotch tape. Furthermore, when a protection coat is carried out with an epoxy resin, most photocurrents are no longer observed by the fatal thing.
[0022] (Example 1)
In the example 1 of reference, the semiconductor device was similarly produced as electrode 2a and 2b except using aluminum instead of gold. When the homogeneous light as well as the example 1 of reference was irradiated, the photocurrent of 600pA was observed. The photocurrent was observed even if it changed the wavelength of the homogeneous light with 300,500,600,700nm. Therefore, it was admitted that this component could detect a photocurrent in a visible region from ultraviolet. Furthermore, when applied voltage was set to 100V, it was admitted by a photocurrent's becoming 10 times and impressing large electric field that an optical large response was obtained.
[0023]

[0024] (Example 2)
The semiconductor device was produced in the above-mentioned example 1, using the cast film as a fullerene thin film 3. Like the example 1, using the spinner, the liquid made to dissolve the carbon cluster C60 in toluene was dropped, the cast film 3 of C60 was produced, the vacuum drying was carried out and the semiconductor device was produced at 100 more degrees C for 1 hour on electrode 2a which vapor-deposited aluminum on slide glass 1, and 2b. 1V are impressed to this component and they are 400nm and 5 mW/cm2. When the homogeneous light was irradiated, the photocurrent of 425pA was observed.
[0025] (Example 3)
The semiconductor device which has the configuration shown in drawing 4 was produced. Width of face of 0.5cm and die length of 3cm were etched with the hydrochloric acid on 3cm 2cmx indium tin glass (ITO glass) 1, the conductive film was removed (part equivalent to 1in drawing 4 a), and the conductive remaining film was made into indium oxide (ITO) electrode 2b. On this electrode 2b, the polymer distribution film 3 of C60 was produced for the dispersion liquid (60; 20mg of C, vinyl acetate;20mg, ethyl acetate; dispersion liquid which put the glass bead into 200mg and were distributed with the paint shaker for 1 hour) which made vinyl acetate / ethyl-acetate solution distribute C60 using bar coating-machine #10. The vacuum drying of this film 3 was carried out at 100 degrees C for 1 hour. Thickness was 1 micrometer. Subsequently, aluminum (width-of-face [of 0.5cm], die length of 1.5cm) electrode 2a was formed with three pieces and vacuum deposition on this film 3. From the function generator, the triangular wave of -2V to +2V was impressed at a scanning speed of 0.001Hz between this indium oxide electrode 2b and aluminum electrode 2a. The current-voltage characteristic at this time was shown in drawing 5 . The rectifying action was shown so that clearly from drawing 5 . On this component, although 3 sets of electrodes were formed, the repeatability was good. Moreover, even if it carried out the protection coat of the whole with the epoxy resin, the current-voltage characteristic hardly changed. Therefore, it was admitted that this component was an outstanding rectifying device.
[0026] (Example 4)
In the above-mentioned example 3, except having replaced with the indium oxide electrode and having prepared tin-oxide electrode 2b by using NESA glass instead of ITO glass, when the semiconductor device was produced similarly, this thing showed the good rectifying action like the thing of an example 3.
[0027] (Example 2 of a comparison)
In the above-mentioned example 3, the semiconductor device was similarly formed except using a non-metal phthalocyanine instead of C60. Also in this case, the rectifying action was shown similarly. However, when a protection coat was carried out with an epoxy resin, the rectifying action decreased greatly.
[0028] (Example 5)
The semiconductor device which has the configuration shown in drawing 4 was produced. Up 0.5mmx3cm of the 2cmx3cm glass substrate 1 was covered, and on this substrate 1, vacuum deposition of the aluminum was carried out to the thickness of a 200 ONGUSU toe ROM, and it considered as electrode 2b (permeability of the 400nm homogeneous light; 2.18%). Furthermore, on this, vacuum deposition of C60 was carried out to 1000A thickness like the example 1 of reference, and the vacuum deposition film 3 of C60 was formed. Subsequently, on it, vacuum deposition of the two a3 0.5cmx1.5cm aluminum electrodes was carried out, and the semiconductor device was formed. When the triangular wave which is -1V to +1V was impressed to this component from the function generator (scanning speed; 0.002Hz), the current-voltage characteristic showed the bidirectional rectifying action as shown in drawing 6 . Moreover, repeatability was good about three electrodes.
[0029] (Example 3 of a comparison)
2000A of alpha-sesquithienyls was vapor-deposited on the top face of the glass plate 1 in which aluminum electrode 2b was formed, like the example 5 (20A/(second)). If it is very hard to vapor-deposit alpha-sesquithienyl and it is vapor-deposited slowly, it will serve as film which decomposed and contained many impurities. Although decomposition will decrease if it vapor-

deposits quickly (20A/(second) or more), an impurity is contained too. Subsequently, 0.5cmx1.5cm aluminum electrode 2a was prepared by three-piece vacuum evaporationo. The triangular wave of -2 to +2V was impressed to this component from the function generator (0.002Hz). This component showed a rectifying action, or did not show it, and its repeatability was very bad.

[0030] (Example 6)

The homogeneous light of wavelength;400nm and on-the-strength;700 microwatt/cm 2 was irradiated from the glass plate 1 side at the electrode, impressing 0.1V to aluminum electrode 2a of the semiconductor device obtained in the example 5, and 2b. The photocurrent of 535nA was observed at this time. When changing the wavelength of exposure light, the photocurrent has been observed to the 800nm homogeneous light. Moreover, by the homogeneous light with a wavelength of 400nm, when changing optical reinforcement, the photocurrent also increased according to exposure light reinforcement. Moreover, repeatability was good about three electrodes.

[0031] (Example 7)

The semiconductor device which has the configuration shown in drawing 4 was produced. Up 0.5mmx3cm of the 2cmx3cm glass substrate 1 was covered, on this substrate 1, platinum was stuck by sputtering and platinum-electrode 2b was formed. Subsequently, the polycarbonate polymer distribution film 3 of C60 was formed with the spinner, and it dried. Subsequently, aluminum electrode 2a was formed with vacuum deposition. The rectifying action was observed when the triangular wave of +1V was impressed from -1 like the example 5.

[0032] (Example 8)

When the platinum vacuum evaporationo film was replaced with the carbon-shadowing film in the above-mentioned example 7 and carbon-electrode 2b was prepared, the rectifying action was shown similarly.

[0033] (Example 9)

In the above-mentioned example 5, except using C70 instead of C60, similarly, when the semiconductor device was obtained and measured, the current-voltage characteristic showed the same bidirectional rectifying characteristic.

[0034] (Example 10)

In the example 7, silver electrode 2b was formed with vacuum deposition instead of the platinum electrode. This component showed the rectifying action like drawing 5 similarly. Moreover, the photocurrent was observed when on-the-strength 1 mW/cm2 and the 450nm homogeneous light were irradiated from an aluminum electrode side.

[0035] (Example 11)

In the example 7, copper-electrode 2b was formed with vacuum deposition instead of the platinum electrode. This component showed the rectifying action like drawing 5 similarly. Moreover, the photocurrent was observed when on-the-strength 1 mW/cm2 and the 450nm homogeneous light were irradiated from an aluminum electrode side.

[0036] (Example 12)

In the example 3, instead of ITO glass and an indium oxide electrode, when others were performed like the example 3 using what formed zinc-oxide electrode 2b by sputtering on the glass substrate 1, the same rectifying action was observed.

[0037] (Example 13)

The same component as an example 5 was formed. First, after forming aluminum electrode 2b on a substrate, it once took out in air and was left under the room temperature for 24 hours. Then, it put in in the vacuum evaporation system, vacuum deposition of C60 was carried out to 1000A thickness like the example 5, and the vacuum deposition film 3 of C60 was formed. Then, two pieces were vapor-deposited for 0.5cmx1.5cm aluminum electrode 2a, one piece was vapor-deposited for the golden electrode, respectively, and the semiconductor device was formed. The permeability of electrode 2a (aluminum, gold) and 400nm homogeneous light of 2b was 2%. After component formation, also when the current-voltage characteristic of -1-+1V was measured immediately, and electrode 2a was any of aluminum and gold, a rectifying characteristic like drawing 5 was shown. Moreover, when 1V were impressed between electrode 2a and 2b, 2 was

irradiated at aluminum electrode 2b and the homogeneous light was irradiated at the wavelength of 400nm on the strength of 5mW/cm, as compared with the time of irradiating the same light as aluminum electrode 2a or golden electrode 2a, the about 25 times as many photocurrent as this was observed. When argon etching of this component was carried out from the electrode 2a side using ESCA and the presentation of the membranous thickness direction was analyzed, it was admitted that the aluminum oxide existed in the interface of C60 film 3 and aluminum electrode 2b.

[0038] (Example 2 of reference)

Commercial crude soot was refined and C60 and C70 were obtained. First, 4g (vacuum metallurgy incorporated company make) of crude soot containing fullerene was put into the extraction thimble, and it extracted by n-hexane;200ml for 24 hours using the Soxhlet extractor. Subsequently, the solvent was changed into mesitylene;200ml and the extract was performed for further 24 hours. When the first n-hexane solution was analyzed by liquid chromatography (silica gel - n-hexane), the ratio of C60:C70 is 9:1 and did not contain most of 70 or more C fullerene. The ratio of C60:C70 is about 6:4, and the mesitylene extract was carrying out variety content of the 70 or more C fullerene. n-hexane extract was condensed by the evaporator and 0.26g fullerene mixture was obtained. Using the ODS column, the mixed solvent of a 2-propanol / toluene;6/4 was used as the developing solution, and 0.21g and 0.02g of high grades C70 were obtained for the high grade C60 using inside low voltage preparative chromatograph. The mesitylene extract was condensed by the evaporator and mixed fullerene 0.13g was obtained. It isolated preparatively by the chromatograph similarly and mixture;0.01g of 60; 0.07g of high grades C, 70; 0.04g of high grades C, and other fullerene was obtained. Mixture contained C76, C78, C84, and fullerene with still larger molecular weight from GC-MS analysis.

[Translation done.]

* NOTICES *

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2.**** shows the word which can not be translated.
3.In the drawings, any words are not translated.

DESCRIPTION OF DRAWINGS

[Brief Description of the Drawings]
[Drawing 1] It is what showed the semiconductor device of this invention, and an example of a circuit, and is the sectional view where (a) meets a top view and (b) meets the A-A line in (a).
[Drawing 2] It is what showed the semiconductor device of this invention, and an example of a circuit, and is the sectional view where (a) meets a top view and (b) meets the A-A line in (a).
[Drawing 3] It is what showed the semiconductor device of this invention, and an example of a circuit, and is the sectional view where (a) meets a top view and (b) meets the A-A line in (a).
[Drawing 4] It is what showed the semiconductor device of this invention, and an example of a circuit, and is the sectional view where (a) meets a top view and (b) meets the A-A line in (a).
[Drawing 5] It is the graph which showed the example of the current-voltage characteristic of the semiconductor device of this invention.
[Drawing 6] It is the graph which showed the example of the current-voltage characteristic of the semiconductor device of this invention.
[Description of Notations]
2a, 2b -- An electrode, 3 -- Fullerene thin film

[Translation done.]

* NOTICES *

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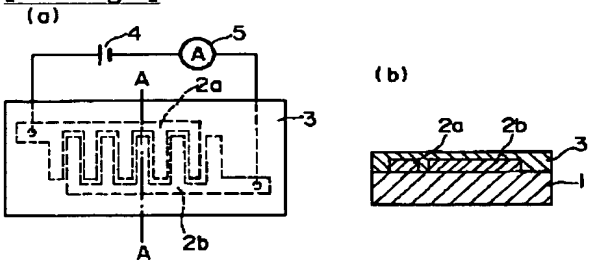
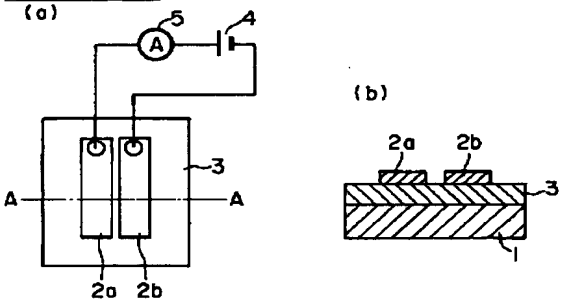
2.**** shows the word which can not be translated.
3.In the drawings, any words are not translated.

DRAWINGS

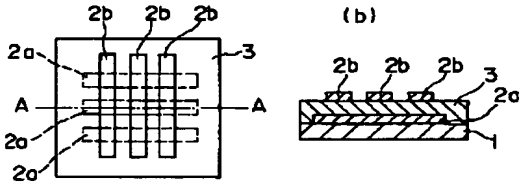
[Drawing 1]



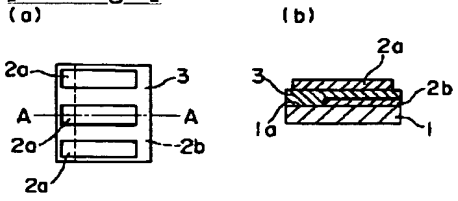
[Drawing 2]



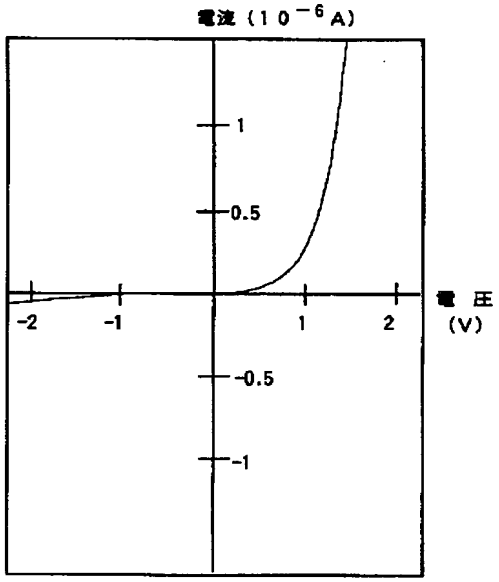
[Drawing 3]



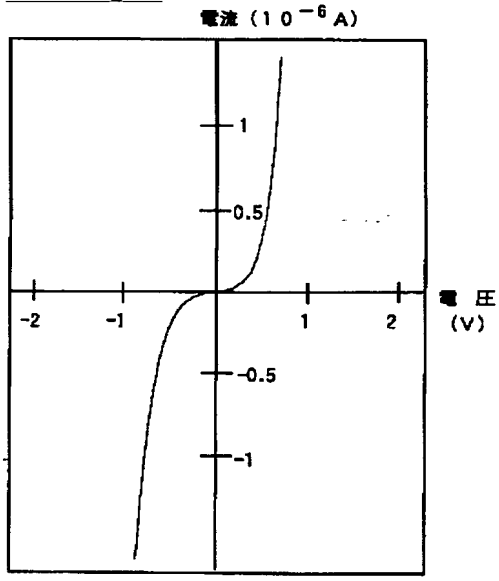
[Drawing 4]



[Drawing 5]



[Drawing 6]



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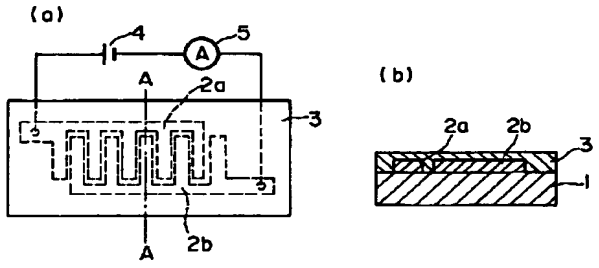
(54)【発明の名称】　半導体素子

(57)【要約】
【目的】　有機半導体素子で、改善された半導体素子、特に整流性および光センシング機能を有する半導体素子を提供する。
【構成】　本発明は有機物で構成される半導体素子であって、半導体としてフラーレン類、特にカーボンクラスターＣ６０及びＣ７０から成る群から選ばれた１種以上を用いて薄膜３を形成し、この薄膜に接するように電極２ａ，２ｂを設けて半導体素子を構成する。
【効果】　整流性、光センシング機能等を有するとともに、機械的強度に優れ、再現性の良い半導体素子が得られ、整流素子、トランジスター、光センサー等に有効に用いることができる。



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【特許請求の範囲】
【請求項１】　フラーレン薄膜およびこれに接する２つ以上の電極を有してなることを特徴とする半導体素子。
【請求項２】　フラーレン薄膜が、カーボンクラスタで構成される薄膜であることを特徴とする請求項１記載の半導体素子。
【請求項３】　フラーレン薄膜が、カーボンクラスタＣ６０および／またはカーボンクラスタＣ７０で構成される薄膜であることを特徴とする請求項１または２のいずれかに記載の半導体素子。
【請求項４】　フラーレン薄膜が、真空蒸着膜、キャスト膜およびポリマー分散膜からなる群から選ばれる１種以上であることを特徴とする請求項１ないし３のいずれかに記載の半導体素子。
【請求項５】　電極が、金属電極、酸化物電極、および炭素電極からなる群から選ばれる１種以上であることを特徴とする請求項１ないし４のいずれかに記載の半導体素子。
【請求項６】　電極が、白金、金、銀、銅、アルミニウム、インジウム、酸化スズ、酸化インジウム、酸化亜鉛および炭素からなる群から選ばれる１種以上の材料からなる電極であることを特徴とする請求項５記載の半導体素子。
【請求項７】　少なくとも１つの電極がアルミニウム電極であることを特徴とする請求項６記載の半導体素子。
【請求項８】　アルミニウム電極がフラーレン薄膜との界面にアルミニウム酸化物層を有することを特徴とする請求項７記載の半導体素子。
【請求項９】　電極が、ギャップ電極またはサンドイッチ電極であることを特徴とする請求項１ないし８のいずれかに記載の半導体素子。
【請求項１０】　半導体素子が、整流素子であることを特徴とする請求項１ないし９のいずれかに記載の半導体素子。
【請求項１１】　半導体素子が、光センサーであることを特徴とする請求項１ないし９のいずれかに記載の半導体素子。
【発明の詳細な説明】
【０００１】
【産業上の利用分野】本発明は、有機半導体素子に係わり、特に優れた整流性および光導電性を有する半導体素子に関する。
【０００２】
【従来の技術】半導体素子の分野では、従来、硫化カドミニウム、酸化亜鉛、結晶シリコン、アモルファスシリコン、ガリウム砒素など無機物が使用されてきた。これらは、トランジスター、整流素子、ＩＣ、ＬＳＩ、光センサーおよび太陽電池等に使用されている。しかし、これらの無機物を用いて半導体素子を作製するためには、高度な真空装置、高度な製膜技術および高度な純度規制

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等が要求され、容易にはなし得ないものであった。
【０００３】これに対し、有機物の多様性、半導体性等が注目されはじめ、ポリアセチレン、ポリピロール、フタロシアニン等の有機化合物の半導体性、導電性について多大な研究がなされてきた（「新・導電性高分子材料」、雀部博之監修、シーエムシー、（１９８７））。特に、導電性高分子あるいは有機半導体を、金属で挟持してなる半導体素子として、ポリアセチレン、ポリジアセチレン、ポリピロール、α－セスキチエニル、フタロシアニン等の半導体薄膜（Ｓ）を金属電極（Ｍ）で挟持してなるＭＳ素子、あるいは間に絶縁体の薄膜（Ｉ）を挟持してなるＭＩＳ素子等多くの素子が提案されている（「Physics of Semiconductor Devices」、2nd Edition、S.M.Sze,John Wiley & Sons,NY(1981)、D.Fichou, F.Garnier et al., CHEMTRONICS, 1988,176頁）。これらの有機化合物はＰ型あるいはＮ型の半導体性を示し、仕事関数の小さい電極と仕事関数の大きい電極で挟持したとき整流性を示す。例えば、α－セスキチエニルの場合（D.Fichou,F.Garnier et al., CHEMTRONICS, 1988,176頁）、これをアルミニウムとインジウムチンオキサイド（あるいは金）電極で挟持したとき±１Ｖで１００倍以上の整流性を示す。さらに、異種導電性高分子の接合で、整流素子を構築した例（Pt｜ﾎﾟﾘﾋﾟﾛｰﾙ｜ﾎﾟﾘﾁｵﾌｪﾝ｜In、M.Aizawa,H.Shirakawa, Synth.Met., 18号, 711頁(1987)）、ＦＥＴを構築した例（H.Koezuka, et al., Synth.Met., 18号, 699頁(1987)）も知られている。また、フタロシアニン等は光導電性を示し、太陽電池等への応用が検討され、アルミニウムおよびＩＴＯガラス（酸化インジウム～酸化スズ薄膜による導電性ガラス）で挟持した太陽電池が検討されている。
【０００４】
【本発明が解決しようとする課題】上記の有機化合物は一般にＳ層すなわち導電性高分子層あるいは有機半導体層の不安定性（ポリアセチレンに於ける空気、湿度等に対する不安定性、ドーピング後の不安定性等）、不純物の混入による再現性の低下（α－セスキチエニル、フタロシアニン等は濃硫酸程度しか溶解する溶媒が無く純度の向上が非常に困難である）、素子形成時の不確定性（気相重合、電解重合等による触媒、電解質等の混入等、α－セスキチエニル、フタロシアニン等の真空蒸着時の熱分解による不純物の混入）、素子形成後の電極の腐食（ドーパントによる電極の腐食、フタロシアニンに見られるようなアルミニウム電極の酸化促進等）、薄膜の機械的脆さ（α－セスキチエニル、フタロシアニン等の真空蒸着膜はこすると剥がれる）等によりいずれも実用化に至っていない。さらに太陽電池では、その経時劣化、変換効率の低さから実用化に至っていない。わずかに有機物で実用化されたものは、ポリアニリンを用いたポリマーバッテリー、ＴＣＮＱを用いたコンデンサー、フタロシアニン等を用いた電子写真感光体程度であり、

見るべき成果がないのが現状である。

【０００５】

【課題を解決するための手段】本発明者らは、従来の導電性高分子をはじめとする有機半導体の上記の如き種々の欠点に鑑み、これらを改良すべく鋭意検討を行った結果、フラーレン薄膜を用い、これに接するように２つ以上の電極を設けることにより、容易に再現性よく半導体素子が得られ、前記課題も解決することができることを見い出し、本発明を完成するに至った。

【０００６】すなわち、本発明はフラーレン薄膜およびこれに接する２つ以上の電極を有してなることを特徴とする半導体素子を提供するものである。

【０００７】以下、本発明を詳しく説明する。本発明で用いられるフラーレン薄膜は、フラーレン類を用いて形成された薄膜である。ここで、フラーレン類とは、ｓｐ２炭素よりなる球状あるいはラグビーボール状のカーボンクラスタの総称であり、一般にＣ６０、Ｃ７０、Ｃ７６、Ｃ７８、Ｃ８４等が知られている。これらは、炭素をアーク放電あるいは抵抗加熱して気化させ、ヘリウム等の不活性ガスで急冷して生成したすすの中等に含有され（例えば、Kraetschmer等、Nature、347号、354頁(1990)等）、Ｃ６０が最も多く含有されている。そしてこのすすから、例えばヘキサン、ベンゼン、トルエン、メシチレン、二硫化炭素等の溶媒で抽出することによって上記カーボンクラスタの混合物が得られる。さらにこの混合物を精製し、各々単離するには、通常有機化合物の精製に用られるクロマトグラフィーの手法（例えば、Kraetschmer等、Nature、347号、354頁(1990)等）を用いることができる。本発明においては、合成、単離が容易なＣ６０またはＣ７０、あるいはこれらを含有するすすから抽出、不溶性不純物除去を施して得られる混合フラーレンが好ましく用いられる。

【０００８】フラーレン薄膜は各種の製膜方法により形成して用いることができ、例えば真空蒸着膜、キャスト膜およびポリマー分散膜等を用いることができる。真空蒸着膜は、例えば一般的真空蒸着の手法に従い（薄膜ハンドブック、日本学術振興会薄膜第１３１委員会編、オーム社（１９８４）等）、5×10^{-5} ｔｏｒｒ以下の真空下で、金属性ボートあるいはアルミナ性ボートなどを用いてフラーレン類を加熱し、その上部あるいは下部に基板を置くことで薄膜を形成できる。この際、必要に応じ、基板を加熱あるいは冷却しても良い。基板を冷却した場合、薄膜はアモルファス状態となり、また、室温あるいはそれ以上に加熱した場合は結晶状態として得られる。このフラーレン類の真空蒸着膜は空気中で安定で、かつ非常に硬く強固である。例えば、従来のフタロシアニン、α－セスキチエニル等はこすれば剥がれ、セロテープ等により簡単に剥離できるように機械的強度に劣るのに対し、フラーレン類の蒸着膜はこすってもなかなか剥がれず、セロテープでは剥離できない強固な膜であり、機械的強度に優れる。

【０００９】キャスト膜は、例えばフラーレン類がベンゼン、トルエン、メシチレン等芳香族炭化水素、二硫化炭素、ｎ－ヘキサン等に溶解する性質を利用するもので、簡便に薄膜を作成しうる手段である。すなわち上記溶媒等に溶解せしめ、基板上に滴下する、あるいは基板をスピンナー上に固定し、上記溶解液を滴下した後、スピンナーを適当な回転数で回転せしめ薄膜化する、あるいは基板上に滴下した溶液をバーコーターまたはドクターブレード等を用いて薄膜化するなどの手段で薄膜化し、次いで自然乾燥、あるいは熱または真空乾燥するなどの手段で乾燥することによって製膜することができる。

【００１０】ポリマー分散膜は、例えばポリマーの溶液中にフラーレン類を添加し、溶解あるいは分散せしめた後、上記キャスト膜と同様の手段で製膜することができる。分散方法としては、ペイントシェーカー、スペックスミキサーミル、サンドミル、ボールミル、アトライター、ニーダー等の顔料分散手法を用いることができる。ここで用いることができるポリマーとしては、特に制限はないが、例を挙げると、飽和ポリエステル、不飽和ポリエステル、ポリカーボネート、ポリ塩化ビニール、ポリ酢酸ビニール、ポリビニールカルバゾール、スチレン等のビニール系ポリマー、フッ化ポリビニリデン、フッ化ポリビニル等のフッ素化ポリマー、スチレン－マレイン酸等のコポリマー等がある。また、例えば、ポリアクリレート系液晶高分子、ポリシロキサン系液晶高分子等の液晶高分子を用いることもできる。

【００１１】フラーレンの優れた半導体性を引き出すには、フラーレン薄膜に接する２つ以上の電極を設けることが必要である。電極としては、例えば金属電極、金属酸化物電極および炭素電極等を用いることができる。例えば、仕事関数の小さいリチウム、ベリリウム、ナトリウム、マグネシウム、アルミニウム、カリウム、インジウム、カルシウム、スカンジウム、チタン、マンガン、ジルコニウム、ガリウム、ニオブ、アンチモン等、または仕事関数の大きいパラジウム、テルル、レニウム、イリジウム、銅、銀、金、白金、ルテニウム、ゲルマニウム、酸化スズ（例えばネサガラス）、酸化インジウム、酸化インジウム～酸化スズ（例えばＩＴＯガラス）、酸化亜鉛、グラファイト、グラッシーカーボン、銀ペーストおよびカーボンペースト等が用いられるが、特に、白金、金、銀、銅、アルミニウム、インジウム、酸化スズ（例えばＮＥＳＡガラス、ＮＥＳＡコートポリマー膜）、酸化インジウム（例えばＩＴＯガラス、ＩＴＯコートポリマー膜）、酸化亜鉛および炭素が好ましい。半導体素子、特にトランジスター、整流素子等として用いるときは、上記の仕事関数の小さい電極と仕事関数の大きい電極を設ける必要がある。但し、アルミニウム電極を用いるときは、本発明の半導体素子は特に双方向の整

流性を示し、双方向スイッチング素子、双方向整流素子等として使用することができる。さらに、アルミニウム電極を形成した後、この電極を空気に曝すと、表面に極薄いアルミニウム酸化物層が形成される。この上にフラーレン薄膜を形成し、次いで任意の電極を形成して構成された本発明の素子も、より高い整流比を示し、整流素子としてさらに望ましいものとなる。一方、光センサーとして用いるときは、電極はいずれの電極を用いてもよく、両極として作用するお互いの電極が異なってもよい。さらに、お互いの電極あるいは一方の電極にアルミニウムを用いるときは、より大きな光電流を得ることができる。特に、上記の如きアルミニウム酸化物層を電極とフラーレン薄膜との界面に形成して得た素子では、さらに大きな光電流を得ることができ、好ましいものとなる。

【００１２】電極は、例えば金属板、炭素板、薄膜、導電性塗料膜等いずれの形態でも使用する事ができる。薄膜の形態で使用するとき、金属箔、蒸着膜、スパッタリング膜、電着膜、スプレー熱分解膜等の手段で薄膜化して使用することができる。また、導電性塗料（例えば銀、炭素含有塗料）を塗布して電極を形成することもできる。ここで、製膜あるいは塗布によって電極を設ける場合には、半導体素子は基板を用いて好ましく形成される。この基板としては特に制限はなく、絶縁性のものであれば良い。また、金属板、炭素板等板状の電極を用いるときは、特に基板を用いなくても良い。

【００１３】電極の構成としては、例えば平行電極あるいは櫛の歯電極等のギャップ電極、またはフラーレン薄膜を挟むように設けられるサンドイッチ電極等を用いることができる。半導体素子、特に整流素子として使用するとき、あるいはギャップ電極で光センサーとして使用するとき、電極の膜厚は任意とすることができる。また、ギャップ電極のギャップ幅は特に制限はないが、ギャップ幅が大きいと電流が小さくなるので、１mm以下のギャップが好ましい。また、ギャップ長は長い方が、電流値が大きくなり、大きな応答が得られるので好適である。ギャップ電極のなかでも、櫛の歯電極を用いると、ギャップ長が更に長くできるのでより好ましい。これに対してサンドイッチ電極で光センサーとして使用するときは、光を入射する側の電極は半透明である必要がある。酸化物電極を用いるときは、光の透過率が９８％～０．１％の範囲が用いられるが、光の透過率が大きい方が光に対する応答性は高い。金属電極の場合、光の透過率が大きい方が光に対する応答性は高いが、透過率が大きすぎると電極が電流を通さない。従って、光の透過率は５０％～０．１％の範囲が好適に用いられる。

【００１４】また半導体素子を構成するフラーレン薄膜の膜厚については、ギャップ電極を用いる場合は、最低１分子の厚みがあれば良く、１０オングストローム～１００μmの範囲で用いることができ、特に１０オングストローム～１０μmの範囲が特に好適に用いられる。サンドイッチ電極を用いる場合は、薄すぎるとお互いの電極が短絡するので、ある程度の厚さが必要である。この場合、フラーレン薄膜の膜厚は１００オングストローム～１００μmの範囲が好適であり、特に好ましくは、２００オングストローム～１０μmに形成される。

【００１５】以上説明したようなフラーレン薄膜および電極を用いて構成される本発明の半導体素子を図面を用いて説明する。図１～４はいずれも本発明の半導体素子の一例を示したものである。図１および図２はいずれもギャップ電極を用いた半導体素子と回路の一例を示したもので、（ａ）は平面図、（ｂ）は（ａ）中のＡ－Ａ線に沿う断面図である。図中符号１は絶縁基板、２ａ，２ｂは電極、３はフラーレン薄膜、４は直流電源、５は電流計である。図１に示した半導体素子は絶縁基板１上に２つの櫛の歯電極２ａ，２ｂが、僅かのギャップを有して噛合するように設けられ、さらにその上面にフラーレン薄膜３が形成されている。また、電極２ａ，２ｂは直流電源４および電流計５を介して接続されている。さらに必要に応じて、フラーレン薄膜３を覆う絶縁性ポリマー膜あるいは絶縁性金属酸化物等の保護膜を形成することもできる。あるいは、図２（ｂ）のように絶縁基板１上にフラーレン薄膜３を形成し、さらにその上面に櫛の歯電極２ａ，２ｂを設けた構成とすることもできる。このようなギャップ電極を用いた半導体素子は、光センサーとして好適に用いることができ、電極２ａ，２ｂに電源４から電場を印加した状態で、フラーレン薄膜３に光が照射されると、電極２ａ，２ｂ間の電流値が変化する。この電流値の変化量は電流計５によって検出され、これに基づいて照射された光強度を測定することができる。

【００１６】図２にギャップ電極を用いた本発明の半導体素子と回路の他の例を示す。この例の半導体素子は、絶縁基板１上にフラーレン薄膜３が形成され、その上面に２つの平行電極２ａ，２ｂが設けられている。さらに必要に応じて、電極２ａ，２ｂおよびフラーレン薄膜３を覆う絶縁性ポリマー膜あるいは絶縁性金属酸化物等の保護膜を形成することもできる。あるいは、図１（ｂ）のように絶縁基板１上に平行電極２ａ，２ｂを設け、その上面にフラーレン薄膜３を形成した構成とすることもできる。

【００１７】図３および図４はサンドイッチ電極を用いた半導体素子の例を示したもので、（ａ）は平面図、（ｂ）は（ａ）中のＡ－Ａ線に沿う断面図である。図３に示した半導体素子は、絶縁基板１上に、短冊状に形成された３つの第１の電極２ａ，２ａ，２ａが平行に設けられ、絶縁基板１およびこれら第１の電極２ａ，２ａ，２ａの上面にフラーレン薄膜３が形成され、さらにこのフラーレン薄膜３上に短冊状に形成された３つの第２の電極２ｂ，２ｂ，２ｂが平行に、かつ上記第１の電極２

ａ，２ａ，２ａと直交するように設けられている。さらに必要に応じて、第２の電極２ｂ，２ｂ，２ｂおよびフラーレン薄膜３を覆う絶縁性ポリマー膜あるいは絶縁性金属酸化物等の保護膜を形成することもできる。ここで、第１の電極および第２の電極の数は、それぞれ１以上の任意の数に設定することできる。このようなサンドイッチ電極を用いた半導体素子は、集積化した整流素子（例えばスイッチング素子等）に好適に用いられ、例えば、液晶、ＥＣＤ等の駆動を行うことができる。または、光センサー（例えばイメージセンサー等）としても好適に用いられる。これらの場合、外部駆動装置（図示せず）から互いに直行する第１の電極および第２の電極に電場を印加して、整流素子あるいは光センサーとして用いることができる。

【００１８】図４はサンドイッチ電極を用いた本発明の半導体素子の他の例を示したものである。このものは絶縁基板１上に、第２の電極２ｂが設けられ、この絶縁基板１および第２の電極２ｂ上全面にフラーレン薄膜３が形成され、さらにフラーレン薄膜３上には、短冊状に形成された第１の電極２ａ，２ａ，２ａが設けられている。この第１の電極２ａの数は、１以上の任意の数に設定することできる。尚、第１の電極２ａは、短冊状だけでなく、円、楕円等いかなる形状でもよい。また、第２の電極２ｂは、基板１上面の一方の端縁部１ａを残して太い帯状に形成され、第１の電極２ａ，２ａ，２ａは、先に形成した第２の電極２ｂの長手方向に直交し、かつこの第２の電極２ｂ上から上記絶縁基板１の端縁部１ａ上に渡って位置するように設けられ、このことにより第１の電極および第２の電極からの配線が短絡する不都合を防止することができる。また必要に応じ、第１の電極２ａ，２ａ，２ａおよびフラーレン薄膜３上に絶縁性ポリマー膜あるいは絶縁性金属酸化物等の保護膜を形成することもできる。このように構成された半導体素子は、単独の整流素子、トランジスター、光センサー等に有効に用いることができる。

【００１９】尚、本発明の半導体素子は、上記実施例の構成に限定されるものではなく、種々の形態が可能であり、結晶、粉末等で構成されても良い。更に、半導体の使用目的により種々の形態をとることができ、これらの目的に基づき、電極および素子の構成は適宜変更されうるものである。

【００２０】

【実施例】（実施例１）図１に示した構成を有する半導体素子を作製した。スライドガラス１上に、ギャップ幅０．１０ｍｍ、電極オーバーラップ１０個、電極全長５０ｍｍの櫛の歯電極２ａ，２ｂを真空蒸着により形成した。電極２ａ，２ｂには金を使用し、５×１０$^{-5}$ ｔｏｒｒの真空下で５００オングストロームの厚さに着けた。この電極２ａ，２ｂを形成したスライドガラス１を真空蒸着器のアルミナルツボ上２０ｃｍに置き、カーボンクラスタＣ６０をアルミナ製ルツボに入れ５×１０$^{-6}$ ｔｏｒｒの真空下で５２０～５５０℃に加熱しながら蒸着し（５オングストローム／秒）、Ｃ６０の真空蒸着膜３を３００オングストロームの厚さに着け、半導体素子を作製した。この素子に１０Ｖの電場を印加しながら、波長；４００ｎｍ、光強度；７ｍＷ／ｃｍ^{2}の単色光を照射したところ、５５ｐＡの光電流が検出された。光強度を０．１、０．５、１．０、２．０、５．０ｍＷ／ｃｍ^{2}と変化させたとき、光強度の増加につれ、光電流も増加した。次いで、この素子を大気中に１ヶ月間放置したが、光電流に変化はなかった。また、Ｃ６０の真空蒸着膜上にセロテープをはり、ついで剥がしたが、Ｃ６０真空蒸着膜は強固に基板に着いており、剥がれなかった。更に、この素子の表面にエポシキ樹脂で保護コートを行ったが、光電流にほとんど変化はなかった。従って、本実施例で得られた素子は、光センサーとして優れた性能を有していることが認められた。

【００２１】（比較例１）上記実施例１と同様にして、スライドガラス１上に形成した電極２ａ，２ｂ上に、カーボンクラスタＣ６０の代わりに無金属フタロシアニンを同様にして真空蒸着し、薄膜３を形成した。実施例１と同様の単色光を照射したところ、１５ｎＡの光電流が観測された。しかしながら、この素子を大気中に１ヶ月間放置したところ¥、光電流は明らかに低下した。また、無金属フタロシアニン蒸着膜上にセロテープを貼り、はがしたところ、無金属フタロシアニンの薄膜はセロテープとともに全てはがれた。更に致命的なことには、エポキシ樹脂で保護コートしたところ、光電流はほとんど観測されなくなった。

【００２２】（実施例２）実施例１において、電極２ａ，２ｂとして、金の代わりにアルミニウムを使用する以外は同様にして、半導体素子を作製した。実施例１と同様にして単色光を照射したところ、６００ｐＡの光電流が観測された。単色光の波長を３００，５００，６００，７００ｎｍと変化させても、光電流は観測された。したがって、本素子は、紫外から可視領域におよんで光電流を検出できることが認められた。更に、印加電圧を１００Ｖとすると、光電流は１０倍となり、大きい電場を印加することにより、大きい光応答が得られることが認められた。

【００２３】（実施例３）図２に示した構成を有する半導体素子を作製した。スライドガラス１上に、すすから抽出し、クロマトグラフィーで、不溶物を除去したフラーレン混合物（液体クロマトグラフィー分析ではＣ６０を８０％、Ｃ７０を１９％含有し、残り１％はＣ７０以上の高次のフラーレン化合物であった）を用いて１０００オングストロームの厚さに真空蒸着し、フラーレン薄膜３を形成した。ついで、ギャップ幅１０μｍ、長さ１０ｍｍのインジウム電極２ａ，２ｂを真空蒸着により形成して半導体素子を作製した。ギャップ電極に１０Ｖの

電場を印加し、波長４００ｎｍ、強度５ｍＷ／ｃｍ²の単色光を照射したところ、４００ｐＡの光電流が観測された。

【００２４】（実施例４）上記実施例２において、フラーレン薄膜３としてキャスト膜を用いて半導体素子を作製した。実施例２と同様にして、スライドガラス１上にアルミニウムを蒸着した電極２ａ，２ｂ上に、カーボンクラスタＣ６０をトルエンに溶解させた液を滴下し、スピンナーを用いて、Ｃ６０のキャスト膜３を製膜し、さらに１００℃で、１時間、真空乾燥して半導体素子を作製した。この素子に１Ｖを印加し、４００ｎｍ、５ｍＷ／ｃｍ²の単色光を照射したところ、４２５ｐＡの光電流が観測された。

【００２５】（実施例５）図４に示した構成を有する半導体素子を作製した。２ｃｍ×３ｃｍのインジウムスズガラス（ＩＴＯガラス）１上において、幅０．５ｃｍ、長さ３ｃｍを塩酸でエッチングして導電性膜を除去（図４中１ａに相当する部分）し、残りの導電性膜を酸化インジウム（ＩＴＯ）電極２ｂとした。この電極２ｂ上に、Ｃ６０を酢酸ビニル／酢酸エチル溶液に分散させた分散液（Ｃ６０；２０ｍｇ、酢酸ビニル；２０ｍｇ、酢酸エチル；２００ｍｇにガラスビーズを入れペイントシェーカーで１時間分散した分散液）をバーコーター＃１０を用いてＣ６０のポリマー分散膜３を製膜した。この膜３を１００℃で１時間、真空乾燥した。膜厚は、１μｍであった。ついで、この膜３上にアルミニウム（幅０．５ｃｍ，長さ１．５ｃｍ）電極２ａを３個、真空蒸着により形成した。この酸化インジウム電極２ｂとアルミニウム電極２ａの間に－２Ｖから＋２Ｖの三角波をファンクションジェネレータより、０．００１Ｈｚのスキャンスピードで印加した。この時の電流－電圧特性を図５に示した。図５から明らかなように、整流性を示していた。本素子上、３組の電極が形成されているが、その再現性は良好であった。また、エポキシ樹脂で、全体を保護コートしても電流－電圧特性はほとんど変化しなかった。したがって、本素子は優れた整流素子であることが認められた。

【００２６】（実施例６）上記実施例５において、ＩＴＯガラスの代りにＮＥＳＡガラスを用いることによって、酸化インジウム電極に代えて酸化スズ電極２ｂを設けた以外は同様にして半導体素子を作製したところ、このものは実施例５のものと同様に良好な整流性を示した。

【００２７】（比較例２）上記実施例５において、Ｃ６０の代わりに無金属フタロシアニンを用いる以外は同様にして、半導体素子を形成した。この場合も同様に整流性を示した。しかし、エポキシ樹脂で保護コートしたとき、整流性は大きく減少した。

【００２８】（実施例７）図４に示した構成を有する半導体素子を作製した。２ｃｍ×３ｃｍのガラス基板１の上部０．５ｍｍ×３ｃｍを遮蔽し、この基板１上にアルミニウムを２００オングストロームの厚さに真空蒸着して電極２ｂとした（４００ｎｍの単色光の透過率；２．１８％）。さらにこの上に実施例１と同様にしてＣ６０を１０００オングストロームの膜厚に真空蒸着し、Ｃ６０の真空蒸着膜３を形成した。ついで、その上に０．５ｃｍ×１．５ｃｍのアルミニウム電極２ａ３個を真空蒸着し、半導体素子を形成した。この素子に－１Ｖから＋１Ｖの三角波をファンクションジェネレータから印加した（スキャンスピード；０．００２Ｈｚ）ところ、電流－電圧特性は図６に示すような双方向の整流性を示した。また、３個の電極について再現性は良好であった。

【００２９】（比較例３）実施例７と同様にして、アルミニウム電極２ｂを形成したガラス板１の上面に、α－セスキチエニルを２０００オングストローム蒸着した（２０オングストローム／秒）。α－セスキチエニルは、非常に蒸着しづらく、ゆっくり蒸着すると、分解し不純物を多く含んだ膜となる。速く（２０オングストローム／秒以上）蒸着すれば分解は少なくなるが、やはり不純物を含有する。ついで、０．５ｃｍ×１．５ｃｍのアルミニウム電極２ａを３個蒸着により設けた。この素子に、－２から＋２Ｖの三角波をファンクションジェネレータから印加した（０．００２Ｈｚ）。この素子は、整流性を示したり、示さなかったりし、再現性が非常に悪かった。

【００３０】（実施例８）実施例７で得られた半導体素子のアルミニウム電極２ａ，２ｂに０．１Ｖを印加しながら、ガラス板１側から、電極に波長；４００ｎｍ，強度；７００μＷ／ｃｍ²の単色光を照射した。この時、５３５ｎＡの光電流が観測された。照射光の波長を変化させたとき、光電流は８００ｎｍの単色光まで、観測できた。また、４００ｎｍの波長の単色光で、光強度を変化させたとき、照射光強度に応じて、光電流も増加した。また、３個の電極について再現性は良好であった。

【００３１】（実施例９）図４に示した構成を有する半導体素子を作製した。２ｃｍ×３ｃｍのガラス基板１の上部０．５ｍｍ×３ｃｍを遮蔽し、この基板１上に白金をスパッタリングで着け、白金電極２ｂを形成した。ついでＣ６０のポリカーボネートポリマー分散膜３をスピンナーで形成し、乾燥した。ついで、アルミニウム電極２ａを真空蒸着で形成した。実施例７と同様に－１から＋１Ｖの三角波を印加したところ、整流性が観測された。

【００３２】（実施例１０）上記実施例９において白金蒸着膜をカーボン蒸着膜に代えて、炭素電極２ｂを設けたところ、同様に整流性を示した。

【００３３】（実施例１１）上記実施例７において、Ｃ６０の代わりにＣ７０を用いる以外は同様にして、半導体素子を得、測定したところ、電流－電圧特性は同様の双方向の整流特性を示した。

【００３４】（実施例１２）実施例９において、白金電極の代わりに、銀電極２ｂを真空蒸着により形成した。この素子も同様に図５の如くの整流性を示した。また、アルミニウム電極側より強度１ｍＷ／ｃｍ²、４５０ｎｍの単色光を照射したとき、光電流が観測された。

【００３５】（実施例１３）実施例９において、白金電極の代わりに、銅電極２ｂを真空蒸着により形成した。この素子も同様に図５の如くの整流性を示した。また、アルミニウム電極側より強度１ｍＷ／ｃｍ²、４５０ｎｍの単色光を照射したとき、光電流が観測された。

【００３６】（実施例１４）実施例５において、ＩＴＯガラスおよび酸化インジウム電極の代わりに、ガラス基板１上に酸化亜鉛電極２ｂをスパッタリングで形成したものを用い、その他は、実施例５と同様に行ったところ、同様の整流性が観測された。

【００３７】（実施例１５）実施例７と同様な素子を形成した。まず、基板上にアルミニウム電極２ｂを形成した後、一旦空気中に取り出し、室温下に２４時間放置した。その後、真空蒸着装置内に入れ、実施例と同様にしてＣ６０を１０００オングストロームの膜厚に真空蒸着しＣ６０の真空蒸着膜３を形成した。引き続き、０．５ｃｍ×１．５ｃｍのアルミニウム電極２ａを２個、金電極を１個をそれぞれ蒸着し、半導体素子を形成した。電極２ａ（アルミニウム、金）、２ｂの４００ｎｍ単色光の透過率は２％であった。素子形成後、直ちに－１～＋１Ｖの電流－電圧特性を測定したところ、電極２ａがアルミニウム、金のいずれの場合にも図５のような整流特性を示した。また、電極２ａと２ｂの間に１Ｖを印加し、アルミニウム電極２ｂに強度５ｍＷ／ｃｍ²、波長４００ｎｍに単色光を照射したところ、アルミニウム電極２ａあるいは金電極２ａに同様の光を照射したときに比して約２５倍の光電流が観測された。本素子をＥＳＣＡを用いて、電極２ａ側からアルゴンエッチングして、膜の厚さ方向の組成を分析したところ、Ｃ６０膜３とアルミニウム電極２ｂとの界面にアルミニウム酸化物が存在しているのが認められた。

【００３８】（参考例）市販の粗製すすを精製してＣ６０およびＣ７０を得た。まず、フラーレン類を含有する粗製すす（真空冶金株式会社製）４ｇを円筒濾紙にいれ、ソックスレー抽出器を用い、ｎ－ヘキサン；２００ｍｌで２４時間抽出した。ついで、溶媒をメシチレン；２００ｍｌに変更し、更に２４時間抽出を行った。初めのｎ－ヘキサン溶液を液体クロマトグラフィ（シリカゲル～ｎ－ヘキサン）で分析したところ、Ｃ６０：Ｃ７０の比は９：１であり、Ｃ７０以上のフラーレンをほとんど含有していなかった。メシチレン抽出液は、Ｃ６０：Ｃ７０の比は約６：４であり、Ｃ７０以上のフラーレンを多種含有していた。ｎ－ヘキサン抽出液をエバポレータで濃縮し、０．２６ｇのフラーレン混合物を得た。ＯＤＳカラムを用い、２－プロパノール／トルエン；６／４の混合溶媒を展開液とし、中低圧分取クロマトグラフを用いて、高純度Ｃ６０を０．２１ｇ、高純度Ｃ７０を０．０２ｇ得た。メシチレン抽出液をエバポレータで濃縮し、混合フラーレン０．１３ｇを得た。同様にクロマトグラフで分取して、高純度Ｃ６０；０．０７ｇ、高純度Ｃ７０；０．０４ｇ、その他フラーレン類の混合物；０．０１ｇを得た。混合物は、ＧＣ－ＭＳ分析からＣ７６、Ｃ７８、Ｃ８４および更に分子量の大きいフラーレン類を含有していた。

【００３９】

【発明の効果】以上説明したように、本発明の半導体素子は、フラーレン薄膜およびこれに接する２つ以上の電極を有してなるものである。この発明の半導体装置は、半導体性、特に整流性、光導電性を示すものである。そしてフラーレン類は、合成が容易で、かつ溶媒に溶解するため、精製が容易で高純度品を容易に得ることができる。また、耐熱性も高く、蒸着時の分解も起こらないため、素子化が容易で、再現性の良い特性が得られる。また、真空を必要としないキャスト膜、ポリマー分散膜の形でも使用できる。したがって、フラーレン類を製膜して得られるフラーレン薄膜を用いることによって、安定性、再現性に富む半導体素子を容易に構成することができる。さらに、本発明の半導体素子は樹脂等を用いた保護コートを施しても性能が変化しない為、広範な用途に用いることができる。特に、整流素子、整流性を用いた液晶、ＥＣＤ素子等の駆動素子、光センサー、あるいは光センサー機能を応用したイメージセンサー等に幅広く応用することができる。

【図面の簡単な説明】

【図１】　本発明の半導体素子と回路の一例を示したもので、（ａ）は平面図、（ｂ）は（ａ）中のＡ－Ａ線に沿う断面図である。

【図２】　本発明の半導体素子と回路の一例を示したもので、（ａ）は平面図、（ｂ）は（ａ）中のＡ－Ａ線に沿う断面図である。

【図３】　本発明の半導体素子と回路の一例を示したもので、（ａ）は平面図、（ｂ）は（ａ）中のＡ－Ａ線に沿う断面図である。

【図４】　本発明の半導体素子と回路の一例を示したもので、（ａ）は平面図、（ｂ）は（ａ）中のＡ－Ａ線に沿う断面図である。

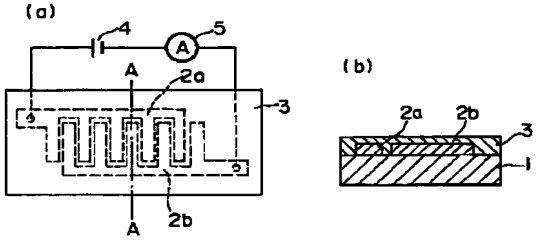
【図５】　本発明の半導体素子の電流－電圧特性の例を示したグラフである。

【図６】　本発明の半導体素子の電流－電圧特性の例を示したグラフである。

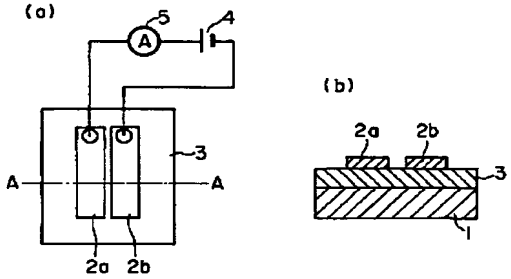
【符号の説明】

２ａ，２ｂ…電極、３…フラーレン薄膜

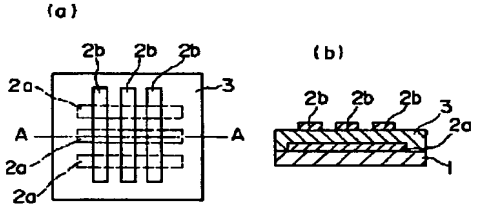
【図１】



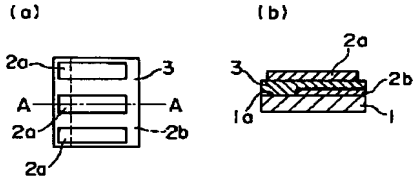
【図２】



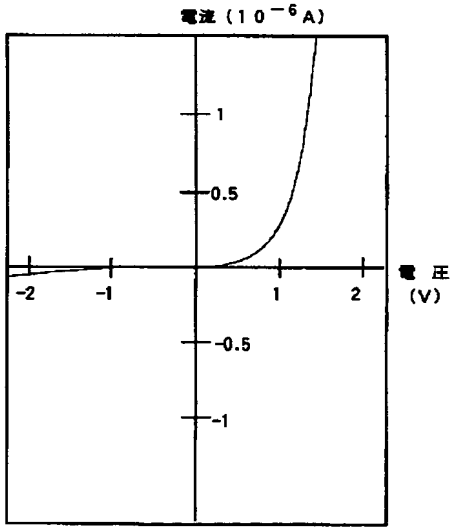
【図３】



【図４】



【図５】



【図６】